ON THE

ATMOSPHERIC CHANGES

WHICH PRODUCE

RAIN, WIND, STORMS,

AND THE

FLUCTUATIONS

OF THE

BAROMETER.

BY

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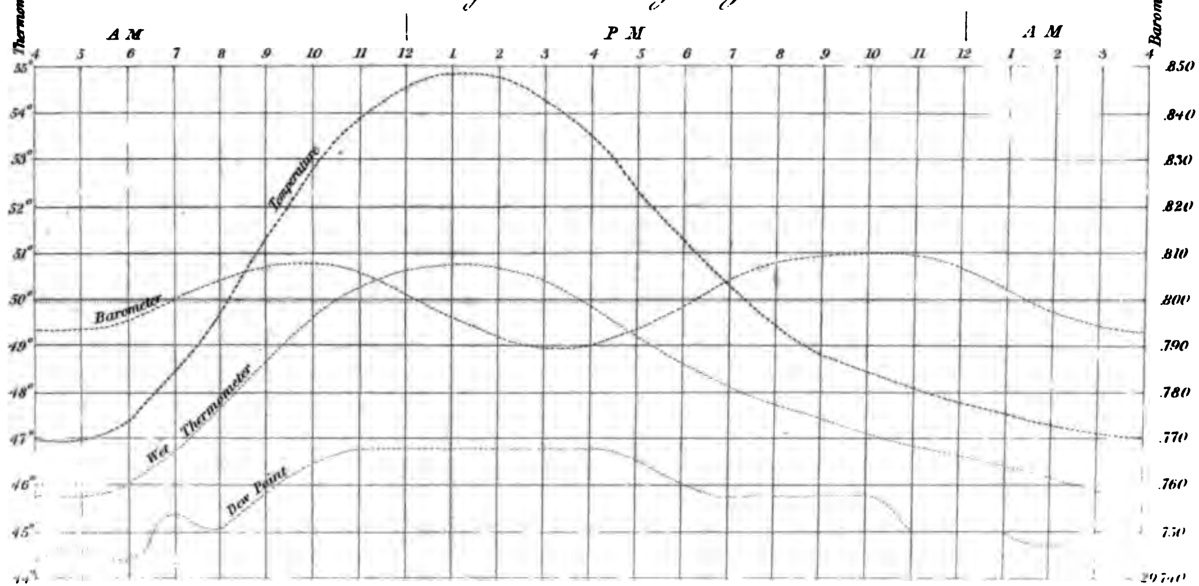
INTRODUCTION.

For many years meteorological phenomena, in Lancashire and its neighbourhood, had engaged a portion of my attention. The winter of 1837-8 I passed in Rome and Naples, where my thoughts were directed to the climate of those places; and, on my return to England, I determined to make inquiries into the causes which produce the atmospheric peculiarities of those parts. What I met with in books, written professedly on meteorology, appeared obscure and unsatisfactory, and I resolved to employ a portion of my leisure in collecting, from travellers, facts likely to throw some light on the subject, and particularly to endeavour to trace the laws of nature in the department of meteorology, where she operates on a large scale: believing that, in so moveable a body as the atmosphere, that was the best course to adopt, in order to see the separate working of each cause. The facts collected in this way at first appeared little better than a mass of contradiction and confusion, but, by putting them into the form of tables, and constructing charts and diagrams, to assist the mind by presenting pictures to the eye, slowly and gradually the influence of general principles appeared as pervading the whole. The facts which were apparently opposed to those principles were then subjected to a more careful examination, and the result was an arrival at the conclusions presented in the following pages. Some of those conclusions were, from time to time, communicated to the Manchester Philosophical Society, and they are now submitted to the public. If they have truth for their basis, they will, probably, be adopted by others; if they have not, I shall only add one to the list of those who have failed in attempting to explain the causes which determine the movements of the atmosphere.

DIAGRAM.

Shewing the mean Hourly Pressure, Thermometer, Hygrometer, and the Dew-point, at Plymouth, during 3 Years.



ON THE

ATMOSPHERIC CHANGES, &c.

THE CONSTITUTION AND MOVEMENTS OF THE ATMOSPHERE.

The aerial ocean that covers the earth, and in which we live, is known to be composed principally of two gases, nitrogen and oxygen, in the proportions of about 79 and 21 in 100. In addition to these there is a small portion of another gas, carbonic acid, computed to be about as 1 to 1500; and as these gases are not condensable, except at very low temperatures, or great pressures, they are commonly called non-condensable gases. They are not united by any chemical affinity, as they intermix in the proportions named, or in any other proportions, with equal facility; they are, therefore, to be considered as diffused through each other mechanically, although found in about the same proportions in every part of the world within a moderate distance from the surface.

These proportions are, however, to some small extent, disturbed by local absorption or generation, and these disturbances are readjusted by the process of mechanical diffusion. But between the generation or the absorption of the gases in particular places, and their complete diffusion through each other, to establish the uniformity of proportions in every part, time will elapse, and the length of time required for the operation becomes a consideration of some importance. Were a quantity of oxygen gas liberated in a

vacuum, it would, in consequence of its elasticity, expand with a certain degree of velocity, determined by its force of expansion, and this may be called its law of expansion. But if the same gas were liberated in a space occupied by another gas, say nitrogen, of a certain degree of density, the oxygen gas would still expand and diffuse itself through space and through the nitrogen; but, as it would encounter the particles of nitrogen in its progress, it would be impeded in its expansion, and would occupy a longer period of time in effecting it. The rate of expansion in the former case being known, it would express the law of expansion, and if from this rate we could deduct the amount of the impediment encountered we should have the law of diffusion.

The law of diffusion of gases is of considerable importance. During combustion, when our furnaces unite that part of the oxygen of the atmosphere which is in immediate contact with heated fuel with a portion of the fuel, in the absence of draft, it is diffusion which causes a fresh supply of oxygen to press on the remaining fuel, to continue the process of combustion: but the supply of oxygen is much less than it would be if that gas were unmixed with nitrogen, as then the oxygen would be supplied according to the law of expansion, and not according to the law of diffusion. The diffusion of gases, as distinguished from expansion, is, therefore, an important process, viewed only in reference to the movements of the non-condensable gases, which constitute the greater part of our atmosphere. But there is another gas, or aeriform substance, in the atmosphere, called aqueous vapour, or steam, which is condensable at a comparatively high temperature, and the law of diffusion acting on this gas produces peculiar effects on the atmosphere. Steam, unlike the non-condensable gases, exists in the atmosphere contiguous to the earth's surface, in the various parts of the world between the equator and the poles, in very different proportions to the other gases. In some parts, near the equator, steam constitutes $\frac{1}{48}$th part of the whole atmosphere, and this is when the point of condensation of some of the steam, or the *dew-point,* as it is commonly called, is as high as 80° of Fahrenheit. In other parts, at certain distances from the equator, it is say $\frac{1}{60}$th of the whole, and the dew-point is at 73°. Proceeding towards the polar regions the dew-point is found to be respectively at say 52° and at 32°, and the steam will then form not more than a $\frac{1}{120}$th and a $\frac{1}{240}$th parts of the whole atmosphere. There are situations where the temperature is, at times, as low as 90° or even 100° below the freezing point of Fahrenheit, and where, consequently, there must be very little steam in the atmosphere. But as the law of diffusion will cause the steam which is in superior abundance in one part to expand in the direction in which it is deficient in another, there must be a constant expansion and diffusion of steam from parts where it is freely produced to other parts where it is comparatively deficient—from the tropical to the polar regions, and from one locality to another, producing peculiar effects, resulting from the condensability of this aeriform substance. The diffusion of any one constituent of the atmosphere must produce, to some

extent, a movement, not of that gas alone which is diffusing itself, but also of those which it encounters, impinges upon, and carries along with it; and although aerial movements or currents, produced in this way, are generally feeble compared with those produced from other causes, hereafter to be noticed, yet they may, by bringing other causes into operation, be instrumental in creating more powerful currents, and will, at all times, more or less modify those which exist.

It has been long observed that there are streams or currents in the atmosphere, extending over large portions of the globe, which are evidently produced by causes acting with a certain degree of force and constancy; and various speculations have been entered into, and theories formed, to account for these currents, or winds, but the theory now generally recognized is that which was first promulgated by HADLEY, and may be described as follows.

The sun's rays heat the surface of the globe within the tropics more than they do the surface of the temperate and polar regions, and the superior heat is communicated to the air resting upon the surface. The heated air then expands, rises, and flows over, at some certain height, towards the cooler regions, where it becomes itself cooled, and returns, as a lower current, to the tropical part, there again to undergo the same process. But these two aerial currents do not move from the tropical towards the polar regions, and back towards the tropics, in direct lines, as they are modified by the rotatory motion of the earth. This motion is, at the equator, say 1,000 miles an hour, and it becomes less towards the poles, until at each pole it is nothing. Consequently the upper current, from the equator, when proceeding towards either pole, will have a more rapid rotatory velocity, from west to east, than the part of the globe over which it is passing, and it will, relatively to the surface of the globe, to some extent, become a western current, or west wind: the joint effect of the two causes making it say, in the northern hemisphere, a south-west wind. The lower air, which is passing from the poles towards the equator, will be affected in the reverse order, and from a north will be converted into a north-east wind. The same causes produce the same kind of effects in the southern hemisphere. This theory of winds, originally advanced by HADLEY, has been recently maintained by Dr. DALTON, and is now generally recognized as true. MALTE BRUN, in his Geography, adopts it, and Professor FORBES, in his Report on Meteorology, in the transactions of the British Association for 1841, treats it as the established theory.

That the effects of the unequal heating power of the sun on the surface of the globe, and of the varying rotatory velocities of the different parts of the earth between the equator and the poles, must be of the nature described in this theory is sufficiently evident. But it is not equally evident that the causes pointed out in it are adequate to the production of those general winds which are known to exist. The difference in the rotatory velocities of different latitudes must certainly have the kind of effect described upon any winds which pass from the equator to the poles and from the poles to the equator, and the degree of effect will be proportioned to the rapidity of the

passage of the wind from one latitude to another. But the unequal heating of the surface of the globe, and, consequently, of the air near it, by the sun, does not, as will be hereafter shewn more fully, produce those palpable or strong winds which blow in some parts towards, and in other parts from, the tropics. The heating of the surface of the globe, and of the air near it, by the sun, is not a sufficiently powerful cause to produce those winds, though, like the law of diffusion, such surface heating may, and no doubt does, to a certain extent, bring into active operation another and a more powerful cause, and, as we shall see hereafter, one that is fully adequate to their production.

Unequal temperature is undoubtedly the great cause of the movements of the various portions of the atmosphere which constitute winds, but inequalities of temperature in our atmosphere are not produced merely by the partial heating of the surface of the globe, and of that portion of the air which is in immediate contact with it. The heat of the sun acts in two ways on the surface of the globe; one is by attaching itself to the matter of the earth's surface and increasing its temperature, which increase of temperature is, to some extent, communicated to the air which rests upon it, as stated in HADLEY's theory of winds. But there is another way in which the heat of the sun acts: it unites with water, and, by evaporation, forms aqueous vapour or steam, without raising the temperature of the surface where the evaporation is carried on to the same extent that the temperature of dry land is increased: and the heat, thus united to the water, moves away from the part in the steam, and, through the operation of certain causes, is carried to a greater or less distance, where it is liberated, and produces effects which appear to have been, in a great degree, overlooked by writers on this subject, but which effects must be duly estimated if we are to understand the causes of the winds which are found to prevail in various parts of the world.

In the following pages it is proposed to shew that the heat which is thus taken up by steam, in the process of evaporation, is carried away to various parts of the atmospheric regions, and in those parts is liberated on the steam being condensed; and that it is this liberated heat which produces that inequality of temperature that causes the greater part of those aerial movements called winds on different parts of the surface of the globe. The limited power of surface heating in producing winds will be hereafter shewn, at present we proceed to consider the evaporation of water by the sun's heat, and the consequent formation and diffusion of steam; and the subsequent condensation of that steam, and the liberation of the heat.

ON RAIN AND WIND.

It is well known that, by placing water in a suitable vessel over a fire until it be sufficiently heated, a part of the water will rise from the surface in the form of steam. And if this steam, by a proper apparatus, be conducted to a cool part, it will be condensed into water; and the quantity of heat which had been taken up by the steam, in the process of evaporation, may be measured by the progress of time, or the consumption of fuel. The quantity given out in condensation may also be measured by increase of temperature communicated to another body. And it is found that the quantity of heat given out in condensation is precisely the same as that taken up by evaporation—none of it is lost, though, when united with water to form steam, it may be conveyed from one locality to another. This course of evaporation and condensation is familiarly known in numerous processes and works, where the heat from a fire is made to vapourise water in a large boiler, which vapourised water or steam is, by its own condensation, made to heat water in other boilers. Now the heat of the sun, if applied to water by a proper apparatus, would have precisely the same effect as the heat of the fire. The solar heat would raise the temperature of the water, vapourise it, and would be given out to any other substance, on condensation being effected, just as the heat from the fire is known to pass through those various stages. And it is not at the temperature of boiling water alone, that heat may be taken up by evaporation and given out by condensation. Water may be vapourised by heat, and converted into steam, at either higher or lower temperatures, the quantity being proportioned to the heat expended; and an exposure of the steam to lower temperature will condense it. Thus, steam of 250° of Fahrenheit, if turned into air or water of 212°, would be in part condensed. And steam of 212°, if allowed to flow into a temperature of 200°, would also be in part condensed into water, and in like manner in other lower degrees. Atmospheric steam, rising from water of the temperature of 80°, which is common within the tropics, would be in part condensed if it came immediately into contact with water of the temperature of say 70°. Steam from water of 70°, 60°, 50°, 40°, or 32°, would be condensed if exposed to or brought into contact with temperatures below those respective degrees. And even from ice of 30° or 20° of temperature steam may arise which can be condensed by exposure to lower temperatures. In all these cases the heat taken up by the steam in evaporation, is given out by condensation wherever the condensation takes place; and wherever the heat is so given out, it raises the

temperature of the part, and generally of bodies in the part, in proportion to the quantity given out; just as steam from one boiler gives out its heat, on being condensed, to the water of another boiler, and raises its temperature. The following tabular view will exhibit the comparative quantities of heat expended, as measured by time, in converting ice of low temperature into steam. And if we suppose a process the reverse of this to take place, the heat expended would be given out, and would, allowing for alteration of capacity, proportionally raise the temperature of any thing that should receive it. Suppose a vessel, with pounded ice in it, of the temperature of 0° of Fahrenheit, to be placed over a burning jet of gas, of uniform strength, and the times noted in the table will mark the relative quantities of heat required to effect such alteration of the ice, until it is converted into steam.

Seconds of Time.	Quantities of Heat.	Increase of Temperature.	Heat Absorbed.
0	0	0°	
32	32	32°	
140	140		140 Liquidity.
180	180	180°	
1000	1000		1000 Elasticity.
1352	1352	212°	1140 Latent.
			212° Temperature.
			1352 Total.

Here we see, that whilst 1352 of heat was expended, only 212 of it went to raise temperature, leaving 1140 of latent heat, 1000 of which, on condensation of the steam, would be given out to any cold substance with which it was in contact, and consequently might be given to the atmosphere.

The sun is the great source of heat on the surface of our globe, and over a great part of the globe the solar heat is regularly uniting with water, from the surface of both land and sea, and vapourising it. As the vapour is formed it acquires elastic force, and springs into the atmospheric space above the surface, and this evaporation is disposed to proceed until a maximum quantity of vapour is formed, which is proportioned to the temperature of the part. The maximum is one quantity within the tropics, where the temperature is high, and other quantities, at different distances from the tropics, where the temperature is lower; but owing to certain causes, which it is not necessary now to explain, it is seldom that the maximum quantity is found in the lower levels of the atmosphere, as condensation in one place is reducing the quantity almost as regularly as evaporation in another place is increasing it. But, wherever condensation takes place, there the solar heat, which had been united with the water to form steam, is given out, and the temperature raised, and the air in the part warmed.

There are parts within the warm regions of the tropics, where evaporation proceeds until there is so large a quantity of steam in the atmosphere as to admit a temperature of say 80° to condense a part of it, and where, consequently, the dew-point is 80°, that being then the point of condensation. The atmosphere itself may be 81°, or 85°, or 90°, but no higher temperature than 80° will condense any portion of the then existing quantity of steam. In cooler regions evaporation cannot so fully charge the atmosphere with steam, as, if evaporation were to take place at the surface—the cold above would condense a part of the steam as rapidly as it was formed. There are parts where the dew-point is not higher than say 70°, because the cold there condenses a portion of the steam, whenever it is supplied in additional quantities by evaporation from wet surfaces. In other parts the dew-point does not rise higher than 60°, 50°, 40°, or 30°, in the cold season. Now if a part of the atmosphere, fully charged with steam, should, from, any cause, be conveyed from a warm to a cold region, a portion of that steam would be condensed, and fall as rain. And it is sufficiently evident, that either the process of diffusion, or the unequal heating of the surface of the earth, and, consequently, of the air resting on it, is capable of conveying warm and moist air into a colder region than that in which it had received its large amount of moisture. And in this way an atmospheric current, proceeding from warm to cool latitudes, may produce condensation and rain.

But there is another cause of condensation of atmospheric steam, more active and powerful in producing that condensation than change of latitude, which cause is the raising of a part of a moist atmosphere to a greater elevation than that in which it had previously existed. In an atmosphere at rest, it is found that the temperature diminishes, say about one degree for every 100 yards of elevation; and this is attributable to the inferior density, and consequent increased capacity for heat of the atmosphere, arising from the diminished pressure of the portion above. Now any part of the air of the lower region being raised 100 yards, would be subjected to less pressure, and would, consequently, be cooled, say about one degree. On being raised 200 yards, it would be cooled two degrees; 400 yards, four degrees; and so on in proportion to the height. And as there are causes in constant operation, sufficiently powerful to produce movements of the atmosphere, those causes may force currents of air to ascend the sloping sides of ridges of mountains, and thus to become cooled by elevation, and have a part of their steam condensed by that cooling. The elevations of land are extremely irregular, and currents of air, being impelled against those irregularities, would follow their courses, and might, consequently, encounter each other; and some, by forcing their way near the surface of the land, might raise other aeriel currents, and thus cool them in a greater degree, and produce more abundant condensation.

The air in the lower region of the atmosphere may also be raised by the action of the sun on the surface of the globe. When the

each degree of Fahrenheit. An increase of the temperature of a particular mass of the atmosphere, to the extent of only one degree, would, therefore, by augmenting its bulk $\frac{1}{480}$th part, without increasing its weight, give it a decided buoyancy, and the adjoining heavier air would press it upwards. A local increase of temperature of say two, four, or six degrees, would of course give much greater buoyancy to the mass, and cause it to be forced upwards with greater rapidity.

Heat is undoubtedly the great agent in producing atmospheric movements, and it is, we have seen, occasionally conveyed in steam to particular heights in the atmosphere, where it is liberated by the condensation of the steam. Now steam, at a certain height, which, on being condensed, will form a cubic foot of water, liberates heat enough to expand the atmosphere with which it is in contact say 8,000 feet. But the steam itself will then have been changed from an elastic to a non-elastic state, and the elasticity of the steam, which will then have been destroyed, may, for our present purpose, be represented as say 1,300 feet, which, being deducted from the 8,000 feet, leaves an increase of elasticity of 6,700 feet. So that for every cubic foot of water formed by condensation of steam, the atmosphere, in the part where it was formed, would expand and press away adjoining air, or rise and cause an overflow with a force equal to the elasticity of the 6,700 feet; and this force would, therefore, reduce the quantity and weight of the column of air in the part where the expansion took place. On the weight of this column of air being thus made less than that of the adjoining columns, contiguous air would press in to fill up the comparative vacuum, and would become an ascending column similar to heated air in a chimney. For, the adjoining air, being equally charged with steam, would, when it reached an adequate height, have its steam also condensed, furnishing more heat; and the process might be continued as long as there was a sufficient supply of steam. In this way it will be perceived, that the steam which is diffused through a large extent of the atmosphere, and which, with a dew-point of say 56°, constitutes only a $\frac{1}{100}$th part of it, may be brought successively from a wide space to a particular locality, where much rain may fall. And the same process may take place with other dew-points than that named, producing copious rains where the dew-point is high, and moderate showers where it is low.

The different laws of cooling of the non-condensable gases and of steam produce important effects in the atmosphere. On removal of incumbent pressure, and permitting expansion to take place, the gases cool say 5°, whilst the steam would cool only 1°. Through the operation of these different laws of cooling the non-condensable gases, in their ascent to a height of say 500 yards, will cool 5°, whilst the steam that is within them is disposed to cool, by its own expansion, not more than 1°; but as the different gaseous substances are intermingled, the cold of the former is communicated to the latter, and the steam is condensed, not by the cooling consequent on its own expansion, but from that which results from the expan-

sion of the gases! When evaporation of water from the surface of the globe takes place, in a previously dry atmosphere, the steam, as it is formed by its elastic force, rises into the atmosphere, and would, by its own law of cooling, have its temperature reduced only 1° for every 500 yards of height to which it might ascend; but it has to expand into, and pass through, the interstices of the gases, which have a temperature that is found lower by 1° for every 100 yards of height. The steam, in rising, is consequently cooled by the cold gases into which it has to expand, and thus condensation commonly goes on at some moderate elevation in the atmosphere, whilst evaporation is proceeding on the surface below. The condensation forms cloud, and warms the atmosphere in the part, and, generally, it will be found that the temperature in the newly-formed cloud will be only about one-half as much reduced by altitude as that of the neighbouring air, which has been undisturbed by recent condensation:—that is, in newly-formed cloud the temperature will be lower only half a degree for every 100 yards of height, whilst in clear and undisturbed air it will be one degree lower at the same height; the cloud will, consequently, be lighter than the adjoining air, and will be liable to be pressed upwards by the superior weight of the cool air, and may form an ascending current. When the atmosphere is thus heated, raised, and expanded in a particular locality, the adjoining more dense air presses into the comparative vacuum, and being in its turn heated, and a continued ascending current created, more distant air rushes in, and thus a horizontal current of air is produced, and *a wind* is the result—and this wind is feeble or strong according as condensation is moderate or energetic.

It having appeared obvious that the gradual cooling of the atmosphere, by passing from a warm to a cool latitude, could not produce such rains as frequently fall to the earth, a theory has been advanced—first, by Dr. HUTTON, to account for those rains, which has had the powerful support of Dr. DALTON. This theory teaches that "When two currents of air, of different temperatures, both fully charged with steam, are intermixed, a mean temperature of the two is obtained. But this mean temperature will not admit the same quantity of steam to exist in the elastic form, in the mixed air, as that which had been contained in the two separate currents, with the two temperatures, a part of it is, therefore, condensed, and falls as rain."

After explaining this theory, Dr. PROUT says, "It must, however, be allowed, as we have before stated, that the utmost information which we can at present bring to bear upon the subject of the general condensation of moisture from the atmosphere, and of rain in particular, *leaves it involved in considerable obscurity*."—*Page* 327 *of Chemistry, Meteorology, &c. in his Bridgwater Treatise.*

With reference to this theory it is sufficient to observe, that masses of air cannot intermix intimately, as is here assumed, except by a slow process, and that process could not produce such falls of rain as very frequently occur. Different gases diffuse themselves

through each other with less or more rapidity, because such gases are merely temporary impediments, and not barriers to the passage of each other; but any one gas is a barrier to the penetrating power of the same kind of gas. A mass of oxygen, by its elastic force, does not penetrate another mass of oxygen, any more than one mass of water penetrates another mass of water which presses against it; and, therefore, when two masses or currents of oxygen of different temperatures come in contact, they are disposed to arrange themselves in their masses according to their densities, and not to penetrate each other. The outer parts may indeed be conceived to penetrate each other to some small extent, but they evidently could not proceed so far as to produce extensive condensation. The same remarks will apply to nitrogen gas and steam, because each of these aeriform substances is equally unable to penetrate a mass like itself. But, though intermixture cannot produce that extensive condensation which must take place when heavy rain falls, if two masses of the atmosphere of different temperatures, fully charged with steam, should strike or press against each other, whilst moving, the process of condensation may be thereby commenced at their lines of contact. And when the process is in this way begun, it may be continued through the agency of ascending heated air, as already explained.

For our present purposes, clouds may be divided into three classes—the stratus—the cumulus—and the cirrus. The stratus is formed simply by condensation, and may be seen in this part of the world in the morning, generally resting on the surface of the sea, and frequently on the land in the summer and autumn. At these times the surface of the globe, particularly during the night, is warmer than the air, and the steam of evaporation, as it rises in the cold air, is slowly condensed into small particles of water, which form a fog or stratus cloud. This cloud may also be formed by the contact, or slight intermixture of currents of air of different temperatures, which are fully charged with steam. On the stratus being, from any cause, raised to a sufficient elevation, it may, by a more energetic action of condensation, be converted into a cumulous cloud, with an ascending aeriel current, forming conical tops; which current may also bear the cloud to a great height. When the cumulus is borne to as great a height as the supply of steam from below will carry it, and when the ascent of the current, resulting immediately from condensation, ceases, it is evident that the liberated heat which it contains, may have made the cumulous cloud warmer than the adjoining atmosphere at the same level. And that adjoining atmosphere, being dry as well as cold, may, in pressing up and following it, cease to supply steam to the cumulus, although that cloud may, through the superior warmth which it retains, continue to ascend. It will become somewhat like a fire-balloon, having warmer and, therefore, lighter air than that in which it floats; and in this state it may rise slowly to an additional height. It will not, however, now have the swelling conical top of the cumulus, but will become a mass, the outer parts of which will begin to dissolve

by evaporation. Or should it meet with different currents of air, it may be elongated or torn in pieces, the outer edges of each piece being dissolved by evaporation, when it would become the cirrus or hairy cloud. The interior portion of these cirri having innumerable small particles of water from which to furnish steam by evaporation, will, for a time, have their maximum quantity of steam for the temperature; and the diffusion of this steam will be more or less rapid as the adjoining air is more or less dry. As these clouds, or pieces of cloud, lose their warmth they will descend to a lower stratum, when they will rapidly dissolve. But it is evident that such clouds may, for a time, form warm beds or strata, at different heights in the atmosphere, or may, by evaporation, greatly cool the locality, and when the whole is in motion, with currents moving at different heights in various directions, may produce an indefinite variety of results.

Writers on climate commonly distinguish between the hot and dry and the hot and moist, and this distinction, founded on experience, is connected with the separate causes that produce the two climates. The hot and dry is produced by the direct action of the rays of the sun on the surface of the earth, warming it and raising the temperature. The surface of the ground is found occasionally to be from 100° to 150° Fahrenheit, whilst the sun pours his heat on the land through an unclouded sky. At night, however, the temperature sinks, the heat being apparently carried away by the air or lost by radiation. The deserts of Northern Africa, Arabia and Persia are samples of this climate. The hot and moist climate is not produced by the sun's rays heating the surface of the earth, but by the heat which is liberated on condensation of steam being effected. The sun is the original source of this heat also, but this is first united with water, and the two form steam, which is frequently carried to parts far distant from the place where the solar heat united with water to form the steam, and in these distant parts the steam is condensed and the heat which it contained liberated, making the part hot and moist. The Carribbean Sea, the Bay of Panama, Hindoostan, and the west coast of tropical Africa, are places possessing the hot and moist climate; and there are other parts of the world which partake of the nature of each of these two climates in various degrees.

When condensation causes air to ascend and other air to rush into the vacuum thus formed, we have wind created from a source other than the partial heating of the earth's surface by the direct rays of the sun, and it becomes an object of inquiry to ascertain what winds are produced by the one and what are produced by the other cause. And in order to accomplish this we will endeavour to trace out those general winds or great atmospherical currents which are known to exist, mark their meteorological and other peculiarities, and note various accompanying circumstances by which they are distinguished, that we may, if possible, discover the real cause that is in operation to produce the wind in each case. By adopting this course we shall bring facts to bear on theoretical reasoning,

and make them test its soundness—whilst that reasoning may advantageously conduct us in a search for facts the most suitable to throw light on this hitherto obscure part of the operations of nature.

ON THE EASTERN TROPICAL TRADE WINDS.

In tracing the direction of particular atmospheric currents we may begin with that which is tolerably familiar to us, and which is known by the name of the "north-east trade wind." It prevails a little to the south of Madeira, more particularly from December to June. Humboldt passed over the line of this wind when he sailed from Spain to America. He left Corunna on the 5th June, and was in sight of Cumana on the 16th July. The temperature of the air in the shade, observed at noon, rose from 50° to 64° in the passage from Corunna to the Canary Islands, and from 64° to 77° from Teneriffe to Cumana. This rise disposes the air to take up water in its passage across the sea from Africa to America, and, accordingly, when it has reached the coast of Guiana and the Caribbean Sea, it is found that the dew-point is considerably raised, and by the time that it reaches the western part of that sea, the dew-point is sometimes as high as 80°.

A part of this atmospheric current passes over Guiana and Columbia to the Cordillera of the Andes, where much of the steam that it had taken with it is condensed and falls as rain. Humboldt says, that "the climate of the mission of San Antonio de Javita, near Rio Negro, on the Upper Oronoco, is so rainy, that the sun and stars are seldom seen," and it "sometimes rained, without intermission, for four or five months."

The *north*-east trade wind is not the only atmospheric current that furnishes steam to this part of the world for condensation. There is another wind from the *south*-east, which may be traced to the same district, and which also comes charged with steam. This trade wind may be found so remote from its place of termination as the western coast of Australia. And it is well known, that the south-east trade wind blows in the southern Atlantic, from the Cape of Good Hope, by St. Helena, to Brazil, where the tenth degree of south latitude is, by sailors, called the heart of the trade wind. This wind, passing over so great an extent of sea, and entering warmer latitudes, must, like the corresponding current in the northern hemisphere, take up nearly its maximum quantity of steam, and by the time that it reaches Brazil it has a high dew-point. A part of this steam is precipitated in the country through which the Oronoco

and Amazon flow, but the principal portion appears to reach the Andes, where condensation is so considerable as to supply those immense bodies of water that flow to the ocean in the channels of the rivers just named. The conversion of so much steam into water, in this locality, must have important effects on the movements of the atmosphere, and on the climates of this and other parts to a considerable distance, but this will be considered hereafter.

In the eastern part of the northern Pacific Ocean, near the tropic, there is no wind corresponding to the north-east trade wind in the Atlantic. The winds which prevail in this part, in the lower region of the atmosphere, are generally from the west. But to the south of the equator a trade wind is found along the coast of Peru, quite as marked in its character as is the similar one we have traced across the southern Atlantic. The whole of Bolivia is arid and desert—Lower Peru is also dry. The province of Piura is particularly dry, and at Truxillo, in latitude 8°, the air is drier than at Lima, in 12° south. It is well known that a south wind blows along the whole of this coast, and as it passes from a colder to a warmer latitude it has its temperature increased, and is disposed to take up rather than deposit moisture. Its northern termination is in the province of Guayquil, near to the equator, where rain falls freely, but as it approaches this part it appears to spread out to the west. And when it reaches the Galapagos Islands, six hundred miles from the continent, it becomes nearly an east wind.

As there is no north-east trade wind in this part in the northern hemisphere, the south wind, just described, seems to be the only source of supply of the tropical trade wind in the Pacific Ocean. C. DARWIN, speaking of it, says—"Oct. 20th, sailed from the Galapagos, and in the course of a few days got out of the gloomy and clouded region which extends, during the winter, far from the coast of South America. We then enjoyed bright and clear weather while running along pleasantly at the rate of 150 or 160 miles a day, before a steady trade wind." The distance to Tahiti is 3,200 miles. "The temperature, in this more central part of the Pacific, is higher than near the American shore. The thermometer in the poop cabin, both by night and by day, ranged between 80° and 83°."—*Voyage in the Beagle, &c. page* 480.

In this part of the Pacific the trade wind is found to extend nearly from tropic to tropic, and is generally steady, excepting where it encounters islands. Abundance of steam exists in it, and when circumstances occur that condense any considerable portion of this steam, the regularity of the trade wind is disturbed. The dangerous archipelago is in about 140° of longitude and 20° of south latitude, and these islands are one of the first groups the trade wind encounters after leaving the neighbourhood of South America. Captain FITZROY says, when speaking of this part—"Singular interruptions to the trade wind occur in the low lagoon islands of the dangerous archipelago. Not only does the eastern wind often fail among them, but heavy squalls come from the opposite direction."—*Voyage in the Beagle, &c.*

The Society Islands are further west and a little more north. Some of these are lofty, and yet the same kind of disturbance of the trade wind is found among them as in the low islands of the dangerous archipelago. Captain FITZROY says—" From the latter end of December to the beginning of March cloudy weather, with much rain and westerly winds, is usual at Otaheitē;" and he adds, " singular interruptions to the regularity of the trade winds occur among all the tropical islands of this ocean."—*Page* 518. The Marquesas Islands are affected in a similar way to the Society Islands.

The Pacific, in the vicinity of the equator, on the northern side, is without islands, within the longitude of which we have been speaking, and the trade wind is there more regular than on the south side. From the longitude of the Society Islands the wind proceeds, with occasional interruptions from various other islands, to the continent of Asia, and the East Indian archipelago. In Captain Cook's third voyage, when speaking of Otaheitē, and the islands to the west of it, it is said that—" In December and January the winds and weather are both very variable; but it frequently blows from the west-north-west or north-west, and then is generally attended by dark cloudy weather, and frequently by rain. It sometimes blows strong, though generally moderate, but seldom lasts longer than five or six days without interruption, and is the only wind in which the people of the islands to the leeward come to this (Otaheitē) in their canoes." This weather, it will be observed, prevails when the sun has reached its southern limit, and when evaporation must have pretty fully charged the southern atmosphere with steam. At other times of the year the wind is different. In the same part of Cook's third voyage it is stated, that " the wind (at Otaheitē), for the greater part of the year, blows from between east-south-east and east-north-east. This is the true trade wind, and it sometimes blows with considerable force. When this is the case, the weather is often cloudy, with showers of rain, but when the wind is more moderate, it is clear, settled and serene." From the tenth degree of south latitude to the twentieth degree north, there are very few islands in the Pacific Ocean between the coast of America and the East Indian archipelago. In this vast space the eastern trade wind blows steadily, the disturbing influence of the islands within, or contiguous to it, scarcely affecting it. It was along this part that the Spaniards, in their early voyages, went from Acapulco to the Philippine Islands. But the eastern trade wind, so mild and steady in the open ocean, becomes disturbed as it approaches the islands of the Indian archipelago, where it assumes a different character.

In its progress westward it encounters the most easterly islands of the archipelago, and in this part of the tropical regions, both south and north of the line, the condensation of the steam brought from the wide range of the Pacific produces very striking effects. Heavy rains fall, the regularity of the trade wind ceases, and winds blow in all directions, so as to constitute it a region of drenching rains and varying storms.

It thus appears that the atmospheric current which is found on the western coast of South America, and which blows from the south along Peru towards the equator, is first a dry and comparatively cool wind. As it approaches the Galapagos Islands it turns more to the west, and shortly after leaving them it is found extending nearly from tropic to tropic, and blowing as an east wind. Among the various groups of islands to the south of the equator the regularity of its current is materially disturbed, more particularly at the period of the year when the southern atmosphere is the most fully charged with steam. But on the northern side of the line, where the sea is quite open, it proceeds in an almost uninterrupted course from the Galapagos to the eastern archipelago. And among the various groups of islands which there lie, both north and south of the equator, the steam which is brought by this atmospherical current is, to a great extent, condensed, producing copious rains, strong winds, and frequent storms.

In the broad expanse of the northern Pacific Ocean it does not appear that any atmospheric current flows from the north towards the tropics, in the lower part of the atmosphere, to constitute, or to add to, an eastern tropical trade wind. But in that part which is near to the eastern coast of Asia a cold wind is found. Navigators all agree that, in our winters, the whole of the coast extending from Kamtschatka to the south of China is very cold for the latitude, and also dry. La Perouse and others have given accounts of the intense cold of winter along this line; and Dobel, the Russian traveller, says—" Towards the last of September or the beginning of October, at Canton, the *Pak Fung*, or north wind, commences. This wind is so remarkable in its effects, and so immediately felt, that should it begin at night, even when all the doors and windows are shut, the extreme dryness of the air penetrates into the house immediately, and the furniture and floors begin to crack with a noise almost as loud as the report of a pistol."—*See Dobel's Travels, vol. 2, page* 195. This wind, in the winter, blows from Japan to the common terminus of all the winds in these parts, the Indian Archipelago, and is felt as far as the island of Borneo, and even to the Java Sea. Malte Brun, when speaking of the Philippine, Molucca and Timorean chains of mountains, says—" In the western parts the rains prevail during the months of June, July, August and part of September, the season of the west and north-west winds; and the adjoining seas are tempestuous, the lands inundated, and the plains converted into wide lakes. At this time the easterly and northerly parts enjoy fine weather. But in October and the succeeding months the north winds, in their turn, sweep the coast with equal fury, accompanied with an equal abundance of rain, and the same inundations take place, so that when the weather is dry in one district it is rainy in the other."—*Page* 48.

The condensation of steam that passes from the north by the China Sea is evidently effected about the islands of the Indian archipelago, and, consequently, towards them this cold current flows as a north and not a north-east wind. Whilst that part of

the same great cold current, which makes its way over central Asia to the Arabian Sea and the Bay of Bengal into the Indian Ocean, and which is known as the north-east or winter monsoon, instead of continuing a north-*east* wind turns and flows as a north-*west* wind to those same islands of the Indian archipelago, where its steam, or a large part of it, is condensed.

Thus it appears, that condensation arrested the progress of the general tropical trade wind among the islands of the Pacific, and sometimes produced an opposite wind; that it caused a north instead of a north-east wind to blow over the China Sea, and converted the north-*east* monsoon into a north-*west* wind in the Indian Ocean. But if condensation can thus cause currents to deviate from their courses, or even reverse them, may not the same condensation produce the currents themselves. Reverting to the first case noticed—may not the condensation, which takes place against the eastern side of the Andes, within the tropics, be a principal *cause* why the winds, called the north-east and south-east Atlantic trades, prevail in their respective localities? Condensation, we have seen, is great on the eastern side of the Andes, and from that region, whence the Amazon and the Oronoco are supplied with water, we may trace the drawing effects of that condensation in the two hemispheres backwards along the two lines of the trade winds to Madeira and the Cape of Good Hope.

Supposing such to be the operation, we may consider this tropical region an area or site of condensation of atmospheric steam, which condensation creates an extensive ascending current in the atmosphere, and air not being able to come over the mountains from the west, the cold currents from both hemispheres press and flow from the east to furnish a fresh supply of air and steam. And the cold currents flow from great distances along particular channels, and not from other quarters, or along other channels, towards this area, because no disturbing causes sufficiently powerful interfere to divert them from those channels. Condensation in this region may thus be considered to act on the trade winds as a *first moving power* or a *cause*, drawing air towards the place where it is in active operation.

If this view is correct, we shall have to consider the different degrees of influence of the direct rays of the sun on surfaces of the tropical and polar regions, as but one of the causes of the great atmospherical currents, and that too the more feeble one; whilst condensation generally in the tropical regions, and in particular localities within them, will be another, and that the more powerful cause! Inequality of temperature being the great cause of all atmospherical movements, that inequality may be found to arise in a greater degree from condensation of steam, than from the difference between the tropical and polar temperatures of the surface of the globe.

Within and near to the tropics the sun is constantly exerting its power, not only in heating the surface of the globe, but also in vapourising water, and raising it into the atmosphere in the form of steam, where a part of it is regularly condensed; and the heat, which

was furnished by the sun during the process of evaporation, is given out when condensation takes place, and a general rise and overflow of the atmosphere in the tropical regions is the result. And if from local causes, such as the existence of elevated land, much condensation should take place in certain parts within the tropics, great heat must be given out in those parts, and the ascending currents would be there particularly strong. Now, the elevated ridge of the Andes, within the tropics, is evidently a local cause of condensation, and as such produces an ascending current, which draws towards itself those portions of the atmosphere in both the northern and southern hemispheres that rest on low levels, and which are the least exposed to disturbing influences. It follows that, to the condensation of steam in this part of America we may attribute the existence of the north-east and south-east Atlantic trade winds.

The same kind of statement and reasoning will apply to the eastern trade wind of the Pacific Ocean. This wind, we have seen, terminates among the islands of the East Indian archipelago, where very copious condensation is known to take place. We may, therefore, consider the condensation of steam, on the eastern side of the archipelago, a principal *cause* of the eastern trade wind which prevails in the tropical regions of the Pacific Ocean; and this cause in its operation extends backwards from the archipelago across the Pacific to America, and then, the mountains preventing any further supply coming from the east, southward along the coast of Peru. And thus these two localities, the Andes and the Indian archipelago within the tropics, become the sites of the active *operating causes* which produce the tropical trade winds.

That condensation of steam, and not difference of surface temperature, is the principal cause of these atmospheric currents may be readily admitted to be possible, because we find that condensation is able to overcome the influence which is supposed to result from difference of surface temperature. Did the latter cause produce the currents, or were it the principal cause of their production, all north-east and south-east winds must have become east winds when they entered the low level regions of the tropics. This follows, as a necessary consequence, on Hadley's theory, because, on that theory, a north-east wind, from the north, and a south-east wind, from the south, when they reach the tropics, must take a course determined by their joint force, and, consequently, must become an east wind. But in the Indian Ocean, south of the line, there is a *south*-east wind which reaches the tenth degree of latitude, and to the north of the line a *north*-east wind, which blows from the continent of Asia, over the Arabian Sea and the Bay of Bengal, into the northern Indian Ocean; but those two winds do not join in the neighbourhood of the equator and become an east wind, blowing on tropical Africa, as they would if the Hadleyan theory were true! No; so far from that taking place, we have seen that the very opposite result is experienced! The north-east wind turns round and flows back as a *west* instead of flowing forward as an *east* wind, and is, finally, absorbed in that ascending vortex which appears to exist

over the islands of the archipelago. Here, then, we have an instance where the influence of condensation of steam is opposed to that of inequality of surface temperature, and where the former is shewn to be the superior force. And if we are to attribute to condensation of steam the prevalence of the north-west wind of the Indian Ocean, why should we not refer to the same cause the tropical east wind of the Pacific? The archipelago is placed within the tropics, with the Indian Ocean on one side to the west, and the Pacific Ocean on the other side to the east, and winds blow towards it from both sides—from the west and from the east: and why should we suppose a different cause to produce the wind on the one side, to that which evidently produces it on the other? There is no valid reason for such a supposition, seeing that condensation is quite as active on one side as on the other, and is as capable of producing the wind from the Pacific as it is that from the Indian Ocean.

And within the Pacific Ocean itself we saw that the small islands, which are scattered over its immense extent, were able to disturb, and even to reverse the general winds, when those islands condensed an adequate amount of steam. Both Captain Cook and Captain Fitzroy state that, when the southern hemisphere was fully charged with steam, heavy rains fell about these islands, and the winds then blew towards them from the west, instead of blowing from the usual eastern quarter. And Captain Fitzroy says that, at the period of the rainy season, these westerly winds extended sometimes across the whole Pacific, by the dangerous archipelago, even to the coast of Guayquil, when heavy rains fell in that part, furnishing, in this reversal of the wind, another striking instance of the paramount influence of condensation of steam in determining atmospheric movements.

ON PREVAILING WESTERLY WINDS.

It has been shewn that the general eastern direction of the tropical trade wind was reversed in the Indian Ocean, as a west wind blows from that ocean to the islands of the eastern archipelago. But that is not the only part within the tropics where a west wind is to be found. On the western coast of Africa, extending from 10° north to say 15° south, in the rainy seasons, westerly winds prevail, and they appear to be produced by the same causes as those which determine a west wind to blow on the eastern archipelago. There are, in the interior of Africa, not far from the equator, mountains sufficiently elevated to condense a large portion of the steam which is there found to exist in the atmosphere. On the

coast very heavy rains fall, as much, according to Major TULLOCH, as 300 inches in the year having been observed in one part; and the interior is known to resemble the coast in this particular. In some maps, one locality, near the equator, to the south, is marked as having perpetual rain! This region of condensation extends, in the interior, to the 15th degree of south latitude. In this part condensation of steam apparently reverses the general eastern direction of the tropical atmosphere, as, during the rains, a north-west, west, or south-west wind is found to blow. The copious condensation extends to only about 15° north—beyond that little rain falls. Presuming these rains to fall south or north of the line, according to the position of the sun throughout the 30° of latitude named, we have a sufficient cause for the westerly winds which prevail on the coast. In the interior of Africa, as over the East Indian archipelago, condensation of steam produces ascending aerial currents, and the western winds blow to feed them, in these parts of the tropical regions.

Another of these winds, although it is not confined to the tropical regions, is the south-west monsoon of the Indian Ocean and parts adjacent. It has been shewn that, in the winter, a north-east wind blows over Central Asia, the Arabian Sea, and the Northern Indian Ocean; in the last-named part becoming a north-west wind by bending eastward towards the eastern archipelago. But shortly after the sun has passed the equator to move farther northward condensation takes place freely on the north side of the line, and it is earliest in the most elevated parts that are near to the line. At the same time the south-west monsoon begins to blow; and, as the sun advances north, condensation in the locality increases, and the monsoon blows more fiercely. The period of the greatest condensation is when the action of the sun has caused the greatest evaporation in the northern hemisphere, and furnished the greatest abundance of steam north of the line. At this time the south-west monsoon rages over the whole of that part of the surface of the globe which is included between the equator and the Himalaya mountains, and along the coast of China, and between say the 60th and 120th degrees of east longitude. Over this space the summer monsoon blows with various degrees of force, and rain falls in various degrees of abundance; the strength of the wind appearing to bear a constant relation to the amount of rain. It has been stated that in a part of the ghauts upwards of 302 inches of rain have fallen in a year. In the '*Bombay Times*,' of August 19th, 1840, is the following account—"We have just heard of a most enormous fall of rain at the Mahabaleshwar hills, amounting, since the beginning of last month, to no less than 134 inches! The greatest fall in one day is 12¾ inches. This is very much beyond the ordinary quantity for the rainy season at the hills, though the fall there does at all times greatly exceed that at Bombay." But a very large amount of condensation also occurs against the south-west side of the Himalaya mountains, where the heavy rains feed the Indus, Ganges, and Bramhapooter. I have not met with any

account of the quantity of rain that falls against these mountains, but it must be great. Major ARCHER says—"Barr is sufficiently elevated to see over the outer ridge into the plains. In the rains neither man nor beast can inhabit it; even the dāk, or post-runners, are obliged to be changed often, owing to attacks of fever."—*P.* 207. These rains are not confined to the plains, or the low hills just above them, but fall freely among the mountains. MALTE BRUN, in his Geography, says—"In the interior and western part of India the rainy season commences in April or May, and continues to the end of October. On the Coromandel coast it begins later, as the clouds which are brought by the south-west winds are detained by the ghauts. While this season lasts it is a rare thing to see the rays of the sun penetrate the dense vapours with which the atmosphere is loaded. In Bengal it rains incessantly for many days. Twenty or twenty-two inches depth are computed to fall in a month."—*Vol.* 3, *page* 25. "The Ganges rises 15 feet by the end of June. By the end of July all the low adjoining land is flooded." —*Page* 19. The great amount of condensation in this part sufficiently accounts for the fierce storms which occur there, and they extend to the China Sea, where they are called typhoons.

The cause of the south-west monsoon is generally said to be found in the heating of the continent of Asia by the sun's rays; this, however, cannot be the cause, as we know that Hindoostan is covered with clouds during the rainy season, but the facts already given furnish sufficient evidence that condensation of atmospheric steam is an adequate cause. And we may, therefore, conclude that the great condensation which takes place in this region produces ascending aerial currents, and, as a supply of air cannot cross the mountains from the north, the air from the equator rushes in, and produces the south-west monsoon. It will hereafter be more fully shewn that sun-heated lands do not produce such winds. If they could the heated land of tropical Africa would draw towards itself the air from that part of the Indian Ocean which lies to the north of Madagascar, and an eastern wind would blow there towards tropical Africa. But the fact is, the south-west monsoon blows in that part, which is from the heated land, and not towards it.

We have thus traced some effects of condensation of steam in producing atmospheric currents within and near to the tropics. But the same process may be discovered in active operation beyond the tropics in both hemispheres, extending into the temperate regions, and in one part even into the polar region, giving rise to atmospheric movements of great extent and importance.

One of these winds is the well-known south-west wind of the Atlantic Ocean, which passes from the northern tropic about the West Indies, and crosses the Atlantic to the north-western coast of Europe. This wind prevails particularly in the latter half of the year about the British islands, and extends to Norway and Iceland, and into the arctic sea, and throughout its whole course is distinguished for its rain and local winds. Rain falls very freely on the western side of the mountains of Norway, and makes the country

warm in the winter, compared with contiguous parts in the same latitudes; there must, consequently, be ascending aerial currents and winds. The western parts of Ireland, England and Scotland, are wet and warm in the winter for the latitude. In Lancashire, at Esthwaite Lodge, 86 inches of rain fell in a year, and at Beddgelert, on the south side of Snowdon, in North Wales, 79 inches fell in 1842. Between Ireland and the United States wind and rain are prevalent, and heavier rains and storms are common in the West India islands. Indeed, the line of this atmospherical current exhibits all the indications commonly seen in those tropical currents which are highly charged with steam, and this may, therefore, be considered a current which has flowed from tropical parts, and which terminates in the regions of condensation about Norway and Spitzbergen.

A current, to correspond with this, is found in the southern hemisphere, which appears to overflow from nearly the same longitude of the tropics, and, doubtless, through the operation of similar causes, to those which give birth to the northern Atlantic current. It is found off the southern part of the coast of Brazil, by ships proceeding from Europe to Hindoostan, in about the 20th degree of south latitude. From this part a *north*-west wind blows across the southern Atlantic, and it passes a little to the south of the Cape of Good Hope. Captain Basil Hall says, in his account of his voyage to Loo Choo—"It is essential to the success of a passage from the Cape of Good Hope to Java, or to any part of India, to run to the southward as far sometimes as 40°, in which parallel the wind blows almost invariably from the westward all round the globe. The requisite quantity of easting is thus easily gained, though at the expense of some discomfort, for the weather is generally tempestuous. This point once accomplished, the ship's head may be turned to the northward, and all sail made to reach the south-east trade. On a knowledge of these particulars the success of eastern navigation essentially depends, and with it, if sailing at a proper time of the year, a fair wind all the way from Madeira to Canton may be obtained."—*Page* 2. This west wind, which blows all round the globe, proceeds to Van Dieman's Land and New Zealand. In a recent account of the colonization of the latter place, it is stated that—"The entire west side of the island is a monotonous line of coast, and, on account of the prevalence of westerly winds, is yet little visited; but in its centre, trending towards the funnel-shaped entrance to Cook's Straits, the high pyramid of Mount Egmont rises like another Peak of Teneriffe, full 10,000 feet above the level of the sea, and serving, consequently, as a conspicuous land mark for ships navigating thitherwards from the west. Its bold snow-covered crest ever shrouded in mist." Here then we may, for the present, consider this current to terminate. It passes over the ocean through about 210° of longitude; that is from 45° west to 165° east, but, unlike the corresponding current in the northern hemisphere, it does not approach the polar region. Both currents, however, flow towards lofty mountains, against which heavy rains fall, and near to which winds and storms are prevalent.

In the great Pacific Ocean there are two aerial currents, similar to those we have just traced; one of them in the northern and the other in the southern hemisphere, and apparently overflowing from the great tropical trade wind of the Pacific. That in the southern Pacific may be traced from the eastern side of the islands of New Zealand across to the continent of America, from 180° to 75° of west longitude. Throughout the whole of this extent there appears to be no land of sufficient magnitude materially to disturb this current, and it, therefore, proceeds in its course until it encounters the western coast of Patagonia and the island of Tierra del Fuego. This part is not much frequented, but we have some accounts of it. Captain FITZROY says—"Beyond the region of tropical or eastern trade winds an almost continual succession of westerly winds is found to prevail. In these middle latitudes easterly winds sometimes blow, but their amount is not more than one-fifth that of the west throughout the year."—*Page* 652. And, when reasoning on the possibility of South America having been peopled from the west, he says—"It is not impossible that vessels should have crossed from New Zealand to South America, running always before the fresh westerly winds so prevalent southward of 38°." As this wind approaches the western coast of the southern extremity of America it assumes a more stormy character; and on this coast there seems to be a larger amount of condensation of steam than in any other part of the world in nearly the same latitude.

Captain FITZROY says—"The climate of western Patagonia is so disagreeable that the country is almost uninhabitable. Clouds, wind, and rain are continual in their annoyance. Perhaps there are not ten days in the year in which rain does not fall, and not thirty in which the wind does not blow strongly; yet the air is mild and the temperature surprisingly uniform throughout the year." And, "From Cape Pillar to Cape Horn the coast of Tierra del Fuego is very irregular and much broken, being in fact composed of an immense number of islands. It is generally bold and free from shoals and banks. The coast varies in height from 800 to 1500 feet above the sea. Further in shore are ranges of mountains always covered with snow, whose height is from 2000 to 4000 feet, and in a few instances about 6000 or 7000 feet."—*Vol.* 2, *page* 312. "Fogs are extremely rare on this coast, but thick rainy weather and strong winds prevail. Westerly winds are prevalent during the greater part of the year." All kinds of shifts and changes are experienced from north to south by the west during summer, which would hardly deserve that name were not the days so much longer, and the weather a little warmer. Rain and wind prevail during the long more than the short days." These extracts are sufficient to shew the climate of this region of condensation, wherein steam, brought by the western atmospherical current of the southern Pacific, is condensed.

Such are some of the meteorological peculiarities of this terminus of the great western current of the southern Pacific. The large amount of condensation of steam must, it is presumed, here produce

a partial vacuum in the atmosphere, and an ascending current which draws air not only from the west, but partially from the south, and as, in both directions, the sea is open, the air which arrives from these quarters is charged with a full portion of steam, and thus copious condensation is continued and perpetuated.

In the Northern Pacific similar phenomena are to be observed, allowing for the effects of local influences. An aerial current prevails from the Japan Isles to the western coast of North America. Captain FITZROY, arguing respecting the possibility of America having been peopled from the west, says—"Neither is it at all unlikely, on the contrary it is highly probable, that Chinese or Japanese junks were driven to the Sandwich Isles, perhaps across to the American coast."—*Page* 652. And again—"Beyond the region of tropical or trade winds an almost continual succession of westerly winds is found to prevail." From the Japan Isles to New Albion and California the sea is quite open, not a single large island exists to disturb the progress of this western atmospheric current, and it, consequently, proceeds to the American coast. Along the whole of this coast, from the Isthmus of Panama to say 60° of north latitude, there are lofty mountains, generally not far from the sea. Reasoning from the principles here maintained, the result, we shall find, must be, that the steam brought from the Northern Pacific Ocean will be condensed against or near to the sides of these mountains, and effects will be experienced near to them similar to those which have been traced at the southern extremity of America—rain will fall copiously, the climate will be warm for the latitude in the northern part, and the whole will be windy and frequently stormy.

Captain BASIL HALL, in his account of the western coast of America, says—"From June to November every part of the south-west coast of Mexico is liable to hard gales, tornadoes, or heavy squalls—to calms, to constant deluges of rain, and the most dangerous lightning: the coast is so unhealthy, at this time, as to be abandoned by the inhabitants." LEWIS and CLARKE passed a portion of an autumn and winter near the mouth of the Columbia river, say in latitude 47°, and the following extracts present a specimen of the way in which they speak of the climate:—"Nov. 11. The wind was still high, from the south-west, and drove the waves (in the river) with great fury against the shore; the rain, too, fell in torrents." "Nov. 24. Since our arrival the weather has been very warm, and sometimes disagreeably so." On the 11th December—"The rain continued last night and the whole of the day; several of the men are beginning to suffer from the excessive dampness." On the 21st—"As usual it rained all night, and continued without intermission during the day." Dec. 31st—"As if it were impossible to have twenty-four hours of pleasant weather, the sky last evening clouded, and the rain began and continued through the day."—*Vol.* 2.

In COOK's third voyage, *vol.* 6, when near Cape Flattery, in latitude 48°, we have this remark in March:—"Thus we had perpetually strong west and north-west winds to encounter." And

some time afterwards it it said—" After leaving Nootka Sound, in latitude 54°, it was stormy. The climate is infinitely milder than that on the east coast of America, under the same parallel of latitude. The mercury in the thermometer never, even in the night, fell lower than 42°, and very often in the day it rose to 60°. No such thing as frost was perceived in any of the low grounds; on the contrary, vegetation had made considerable progress, for I met with grass that was already above a foot high." It was in April.

The same kind of weather is experienced further north, in 60° latitude, so that the steam brought by this western aerial current of the Northern Pacific must be spread along the whole coast, where it is extensively condensed against the western side of the lofty mountains which exist throughout this range, producing those drenching rains that have been described, making the temperature high, and creating ascending aerial currents, strong winds, and furious storms.

In the accounts which have been thus given of a number of aerial currents, they have been traced to various termini; all of which are areas of condensation of steam. The trade wind from beyond Madeira was followed to the Andes; to which locality another wind, from the Cape of Good Hope, was also traced. The south wind of Peru was found to cross the Pacific within the tropics, and terminate among the islands of the eastern archipelago, to which part a west wind also blows from the Indian Ocean, making this group of islands the common terminus of two opposite winds. Westerly winds have been shewn to blow about the middle of the tropical regions towards the mountains of Africa, though the general direction of wind within the tropics has been supposed to be from the East. The south-west monsoon of the Indian Ocean also blows during the summer. So far then, we find that, in the tropics, there are two east and three west winds, and all five terminate against, or among, mountains. Of the winds that blow from the tropical to cooler latitudes, we have seen that, in the northern hemisphere, one reached Norway and Spitzbergen, another to the Himalaya mountains, and a third to the western coast of North America. And in the southern hemisphere one wind passed from Brazil to New Zealand, and another from New Zealand, across the Pacific, to the western coast of South America. All these termini are known to be localities of great condensation of atmospheric steam, where the temperature of the air is evidently increased by liberated heat, and where partial vacui must, consequently, be created, and where it is, therefore, presumed that ascending currents must be formed, making these localities large natural chimnies, towards which atmospheric air flows or rushes with different velocities from great, though varying, distances, but with sufficient force to make them the prevailing winds; overcoming or modifying all minor influences, such as the inequality of surface temperature, and the different rotatory velocities of different latitudes, by the superior energy of condensation of steam, and making the ascending aerial currents, in these areas of condensation, the prime causes and active producers of all the great winds that are found on the globe.

ON SUN-HEATED LAND, AND SEA AND LAND BREEZES.

On no one point do meteorological writers, and those who treat on subjects connected with meteorology, more universally agree than on the influence of sun-heated land, on the adjoining atmosphere, in causing that atmosphere to flow towards the heated land. The heated surfaces of broad continents are pointed out as the causes of strong and long-continued winds; and coasts and islands which have their surfaces heated during the day by the sun's rays, are said, with undoubting confidence, to have that heat communicated to the air resting upon them, which causes the air to rise, and thus admits the cool sea air to flow in by day, producing a sea breeze. And these facts are stated to be observable in many parts of the world, presenting, it is assumed, evidence of the strongest kind to support the opinion that such winds and breezes are caused by the air resting on the heated land, being rarified and raised by the direct influence of the sun's rays.

It is true that regular alternating sea and land breezes are found on coasts of continents and islands in many parts of the world. But, to those who think that they are produced by sun-heated land, it must seem a singular fact, that such breezes should not be found in those parts where the causes which are supposed to produce them exist in the strongest degree! The sun must heat the north-western part of the Sahara, or North African Desert, every day up to a very high temperature, yet no regular sea breeze prevails on this coast. Now, if sun-heated land caused the sea breeze in the way described, how could this be? It is known, also, that the temperature of the land in this part sinks greatly at night, and there is, consequently, that difference of temperature between day and night which it is presumed always produces the sea and land breezes, but no such breezes are found here! The north-east trade wind, in a gentle form, prevails during a great part of the year off this coast, and the atmosphere is clear. To use the language of MALTE BRUN—"The earth beneath is scorching—the sky above is on fire," *on the desert land*, while the trade wind near to it is comparatively cool, and yet there is no sea breeze! It may be said that the trade wind, blowing away from the coast, is sufficiently strong to overcome the tendency of the air to flow from the sea towards the hot desert. That, however, is giving up, in this instance, the theory in question. But we shall see, presently, that the sea and land breezes, where they exist, modify or overpower the general currents of the atmosphere, as on the coasts of Peru and in the islands of the South Sea. But why have we not the daily sea breeze on the more southern part of the coast of this dry African Desert, say in about the latitude of 20°, which part is beyond the influence of the trade wind? In this part no regular sea breeze is ever noticed.

Were it, however, this one part of the world alone, where the cause which is said to produce the sea breeze exists in so very strong a degree, and yet where no sea breeze prevails, it might be considered one of those exceptions which are occasionally met with that cannot be accounted for, but which are not held sufficient to overturn a theory, resting on a great number of other cases, presenting evidence in its favour of a conclusive character. But the north-west coast of Africa is only one instance out of a number which might be named. In the neighbourhood of the Arabian Sea land is found which, in our summers, is heated up to a high temperature. The southern part of Arabia is very hot compared with the temperature of the adjoining sea, but does the air flow from that sea towards and over the heated land? It certainly does not. On the contrary, when the summer monsoon is the strongest, and the land of Arabia the hottest, the wind blows from the west, and, consequently, it blows from the greatly heated land, towards and over the cool sea, or just in the opposite direction to what would be found if the common theory respecting the cause of sea breezes were true. And to the south of Arabia, along the eastern coast of Africa, from Cape Guardafui by the dry desert of Ajan, Zanquebar and Mosambique, extending from ten degrees north to twenty degrees south, there is land so greatly heated as to make it some of the hottest in the world; yet the comparatively cool air of the Indian Ocean does not flow towards this land, but, as on the Arabian coast, the wind blows from the heated land over the cool sea. In Major HARRIS' account of Abyssinia, recently published, is the following passage:—"Landing at Tagura, a port near the entrance of the Red Sea, the embassy crossed the belt of land which stretches for a breadth of three hundred and fifty miles to the mountains. A desert scorched by an ardent sun, and alive only with moving pillars of sand." A popular compilation describes the winds of this part thus—"In the Mosambique channel, the south-*west* monsoon begins in April and continues till November. The north-*west* then succeeds, and continues till April, but does not extend south of 23° of south latitude." "The north-*west* and south-*west* monsoons are weaker and more variable in the Bay of Bengal than in the Gulf of Arabia, where they are more constant as well as more violent. In their progress westward (that is, in their more western part) they gradually range over a wider space; they blow over the whole of that track of sea that lies between Africa and Madagascar from the *west*, north-*west* and south-*west*."—*Lizar's Atlas, page* 37. That is, both monsoons blow from the west along this hot coast, which is from the hot land to the cool sea, in direct opposition to the theory contained in Malte Brun's Geography, and copied into Lizar's Atlas.

But other phenomena, which occur during the prevalence of the south-west monsoon, in another quarter, are, if possible, more decidedly opposed to this theory. If any one part of the broad expanse of the continent of Asia could be heated so as to draw air from the Arabian Sea and the Indian Ocean during the summer, it would be that part which lies between Hindoostan and the Lake of

Aral, including the region between the Valley of the Oxus and Persia, and the land of this part, unlike Hindoostan, is not screened from the sun by thick vapours. But what says BURNES respecting the winds of this part? Why, that about the latter end of June, though the thermometer was at 103° in the day—"In this country a steady wind generally blows from *the north*."—*Page* 18. And on the 23rd August, after having passed the Oxus—"The heat of the sand rose to 150°, and that of the atmosphere exceeded 100°, but the wind blew steadily, nor do I believe that it would be possible to traverse this track in summer if it ceased to blow. The steady manner in which it comes from *one direction* is remarkable in this inland country." Again—"The air itself was not disturbed but by the usual *north* wind that blows steadily in this desert."—*Vol.* 3, *page* 40. And he has many other similar passages. Now, the theory to which we have adverted teaches that the heated air over this land ascended, and allowed the comparatively cool air from the Indian Ocean to rush in to supply its place, and thus to constitute the south-west monsoon. But we see that so far from the south-west monsoon blowing into these heated parts, an opposite wind, namely, the *north*, blew from them towards the parts where the monsoon was then raging, the mountains being, apparently, the common terminus of both!

The belief in the effects of sun-heated land on air, in producing winds, is likely to exercise influence on the conduct of navigators, and may lead them into serious errors. Captain BASIL HALL, when giving an account of navigating a part of the Pacific, which is subjected to similar influences to those which produce the south-west monsoon, has these remarks:—"That portion of the Pacific Ocean which stretches from the Isthmus of Panama to the peninsula of California, lies between eight and twenty-two degrees of north latitude. Now the sun's rays *strike directly* upon the adjacent great territory of Mexico, and, by heating the *land* violently, cause the air to rise over it. But the vacuum is filled up, not only from the northward, but by the comparatively cold air in the equatorial regions, in the neighbourhood." And he goes on to say—"When I was sent to visit the south-west coast of Mexico alluded to, and was left to my own choice, as to the manner of performing the voyage, I miscalculated the probable effect of so vast a heater as Mexico, and expected to find the winds from east or north-east, and, therefore, began my voyage at Panama. I soon learned, however, to my cost, that instead of being to windward of my port, I was dead to leeward of it, and I had to beat against a westerly wind for many weeks."

This part of Mexico has been already alluded to, but it may be desirable again to refer to accounts of it. Humboldt says that along this coast—"Sugar, cotton, cocoa and indigo, are abundantly produced only at an elevation of from 1968 to 2625 feet." And this is the region of heavy rains and malaria. He goes on to state that—"On the declivities, at the elevation of 3937 or 4921 feet, there prevails a mild climate, never varying more than four or five degrees. To this region, of which the mean annual temperature is from

68° to 69°—8′, the natives give the name of "Tierras templados." Unfortunately these tracts are covered with thick fogs, as they occupy the heights to which the clouds usually ascend above the level of the sea." "The plains, which are elevated more than 7218 feet above that level, and of which the mean temperature is under 62°—6′, are named "Tierras frias." Thus it appears that the lower part of this country is very rainy, the middle land is covered with thick fogs, and the upper is cool from its elevation; consequently, the general surface of the ground cannot be made hot by the rays of the sun striking on it. Occasionally parts may be made hot by the direct rays of the sun, but the general character of the country is that which is given by Humboldt. The heat which produced the winds that surprised and baffled Captain HALL, came, there is no doubt, from the condensation of that steam with which the atmosphere in this part is known to be loaded, and not from the direct action of the sun's rays on the surface of the earth. And it is very desirable that persons similarly circumstanced with the Captain, should understand the theory of those operations that are going on around them, and which exercise such an influence over them. Captain HALL regrets that he had not previously considered what a great heater the land of Mexico must be, in order that he might have avoided the winds which blow in that quarter. And with his theory in his mind, whenever he approached a land greatly heated by the sun's rays, he would naturally take the requisite means to avoid the wind which he would expect to be blowing on it. Had he, for instance, been afterwards sent with his ship to serve off the north-west coast of Africa, in the summer, and had expected to find a strong wind blowing towards the land because the adjoining desert was a great heater, he would, as has been shewn, have been as much disappointed off the coast of Africa as he was off the coast of America. The surface of the land in Africa is really a great heater, yet there are no strong or long-continued winds found on the coast, as there are on the west coast of Mexico and Hindoostan. Navigators seldom visit the African coast named, but they pass at no great distance from it, and were there strong winds blowing, would assuredly speak of them. DARWIN says—"At St. Jago, Cape de Verd islands, the atmosphere is generally very hazy; this appears due to an impalpable dust which is constantly falling, even on vessels far out at sea. Afterwards, when the air was clear, the hygrometer gave a difference of 29°—6′ between the temperature of the air and the dew-point." Indeed, from Madeira, by the Canary Islands, along the desert coast to Cape Blanco, and the Cape de Verd islands, either calms or dry winds from the desert are generally met with. The harmatton, or land wind of the desert, is often encountered, and it is this wind which takes the fine dust so far out to sea. The whole of the coast is remarkable for the want of water, in that particular resembling the south coast of Arabia, and the eastern coast of tropical Africa, and in none of those parts does the wind blow from the cool sea to the heated land.

Eastern Patagonia lies between say 40° and 53° south, and the nature of the country may be seen from the following extracts from Captain FITZROY'S Voyages—"Fresh water is seldom found in these wastes; salinas are numerous. The climate is delightful to the bodily sensations, but for the productions of the earth it is almost as bad as any, except that of the Arabian or African deserts. Rain is seldom known during the three quarters of the year, and even in the three winter months, when it may be expected, but little falls, except on rare occasions, when it comes down heavily for two or three days. Sea winds sometimes bring small misty rain for a few hours, at any time of the year, but not enough to do good to vegetable productions. Generally, a bright sunny day is succeeded by a cloudless and extremely clear night. In summer the heat is scorching, but not sultry."—*Page* 339.

This part of America is considerably beyond the tropics, and, therefore, the land is not likely to be heated up to so high a degree as the dry deserts of Africa or Arabia, yet it is stated to be greatly heated, but no mention is made of regular sea winds blowing towards it. Not only, therefore, is the theory to which objections are here advanced unsupported by facts, but the numerous facts to be met with all tend to prove the opposite of the theory; that is, they tend to shew that strong winds blow towards lands drenched with rain and screened with clouds, and that they do not blow towards land strongly heated by the direct rays of the sun.

This theory, so opposed by facts, would probably never have been countenanced, had it not been apparently supported by those movements in the atmosphere, which take place in many parts of the world, called "sea and land breezes." Of these Professor FORBES speaks thus, in his Report to the British Association, published so recently as 1840:—"Land and sea breezes, in all climates, especially between the tropics, are attributable to the more or less heat-absorbing character of the surface of the solid or fluid, in varying the distribution of temperature during twenty-four hours."—*See page* 102 *of the Report.* These breezes certainly often blow towards the land when the sun has heated it during the day, and flow back at night when the land is cooled. And it being concluded, from these observed facts, that each day the sun heated the land caused the air over it to ascend, and admitted cool air to flow in below, it seemed to follow that where extensive lands were greatly heated by the sun cool air must necessarily flow in from adjoining parts.

But what really causes those sea breezes that, in so many parts of the world, are known to blow daily from the sea to the land, as soon as the sun has sufficiently exerted his power? Can any other circumstance than the direct influence of the sun's rays on the earth produce that regular daily wind called the sea breeze? Let us proceed to inquire.

The western part of Peru is one of those localities in which regular day and night, or sea and land breezes, prevail; and it is commonly referred to as a place where the sun, by heating the land during the day, causes the sea breeze to blow. It is, therefore,

desirable that we should inquire what are the peculiarities of this coast which are likely to affect the winds daily. Captain FITZROY, when in Peru, at Point Jara, latitude 23° south, writes thus:—"The tops of the hills on the coast of Peru are frequently covered with heavy clouds. The prevailing winds are from south-south-east to south-west, seldom stronger than a fresh breeze, and often very slight. Sometimes during the summer, for three or four successive days, there is not a breath of wind, the sky is beautifully clear, with a nearly vertical sun. On the days that the sea breeze sets in it generally commences about ten in the morning, then light and variable, but gradually increasing till one or two in the afternoon. From that time a steady breeze prevails till near sun-set, when it begins to die away, and soon after the sun is down there is a calm. About eight or nine in the evening light winds come off the land, and continue till sun-rise, when it again becomes calm until the sea breeze sets in as before." This appears to be a clear description of the sea and land breezes which prevail off this part of Peru; and, lightly read, certainly appears to lead to the conclusion that the sea breeze is caused by the sun heating the land in the way generally supposed. But a fact is stated in this account, namely, that—"Sometimes during the summer, for three or four successive days, there is not a breath of wind, the sky is beautifully clear, with a nearly vertical sun." Such weather as this is described as an exception to the general weather that is found off this coast, and at the time of this exception no sea breeze blew—as it is said that there was "not a breath of wind." Well, what was the the state of the land when the sea breeze thus ceased for three or four days? We ought, on the common hypothesis by which sea breezes are accounted for, to expect that the sun, from some cause, ceased to heat the land, and, therefore, heated air ceased to rise, and cool sea air ceased to blow in from the sea to the land. But we are told by the same writer that, during these four days, "the sky was beautifully clear, with a nearly vertical sun." That is, we are informed, by this careful observer, that at the time when a nearly vertical sun was shining on the land, and greatly heating it, and the sky was beautifully clear, and when, according to the common theory of the cause of sea breezes, we ought to have had such a breeze of the strongest character, there was "not a breath of wind." The coast of Peru, it appears, was, during these four days, in a similar state to that in which the heated deserts of Africa, and other parts already alluded to, are found when, notwithstanding the great heat of the land, no sea breezes were produced.

But at other times sea breezes do blow on this coast, and it, therefore, becomes our business to inquire what are the additional circumstances to be observed in this same part when sea breezes blow, that we may be enabled to account for them. If an observer, after having experienced four days of calm weather, with a clear sky, would have noticed what alteration took place in the sky at the time that the sea breeze began to blow, it is very likely that the cause of the sea breeze might have been discovered, and rendered evident.

I have not, however, met with any statement of that kind, and must, therefore, be content to use such information as can be obtained.

When Captain FITZROY says that, during the calm days, the sky is beautifully clear, he leaves us at liberty to infer that when the sea breeze blew the sky was not beautifully clear. We are at liberty to draw that inference because he does not speak of the sky being beautifully clear at other times, but seems to limit his statement respecting the clear sky to the calm days. He, however, more than once states that, during the summer, "the tops of the hills on the coast of Peru are frequently covered with mist." And in another part of his book, when speaking of an adjoining portion of this coast, evidently affected by similar influences, the Captain states some facts which may enable us to understand what is the real nature of the meteorological changes which are taking place in this part of the world that produce the sea breeze. He says—"In Northern Chili, just before sun-rise is generally the best time for enjoying an unclouded view of the Andes; for scarcely have the sun's beams shot between their highest pinnacles into the westward valleys when clouds of vapour rise from every quarter, and during the rest of the day, with few exceptions, obscure the distant heights."—*Page* 481. Now if what has been advanced in a former part of this work is correct, namely, that a cloud, when raised by the warming influence of the sun, has the steam which it contains condensed into rain, and that thus an ascending aerial current is produced, into which adjoining air will flow, may not the clouds of vapour which rose, as described by Captain FITZROY, in Northern Chili, generally form cumuli against the sides of the Andes, produce ascending aerial currents there, and cause a flow of air from the sea to supply the place of that which had ascended, and thus create sea breeze? Not only may this take place, but, from a consideration of the various facts named, we are authorized to assert that it must occur. The existence of the mist, which rose from every quarter in the morning, proved that the dew-point and the temperature were in the part nearly the same.* When the sun heated the lowest stratum of air the air expanded and rose, taking the steam intermingled with it to a higher region. As this moist air rose, and became subjected to less pressure from air resting upon it, it would cool, and in cooling condense some of its steam. Now if the causes in operation were only just sufficient to produce a small thin cloud during the day against the sides of the mountains, that cloud would merely obscure them to the view, and the day might be calm and the sky clear over the low land of the coast. But if the condensation was sufficient to cause rain to fall freely among the mountains, and air to ascend, other air would be drawn, not from the east, because there lofty mountains intervene, but from over the sea, to supply its place—and thus a sea breeze would blow. And if the dew-point should be high, and the condensation consequently great, the cloud might extend from

* "In the evening of the 12th June," says BASIL HALL, "the land wind was just sufficient to fill the sails, dripping wet with the heavy dew."—Near Lima, in 18° south.

the mountains and cover the adjoining land and some of the sea, whilst a strong sea breeze might be blowing at a considerable distance from the land.

DARWIN says—"During the winter months, both in Northern Chili and Peru, a uniform stratum of clouds hangs at no great height over the Pacific. When on the mountains we had a very striking view of the great white and brilliant fields which sent arms up the valleys."—*Page* 427. These clouds might, in the winter, be so raised as to produce a daily sea breeze of greater or less strength. SMITH, in his account of Peru, says—"In Lima, in February, the thermometer, if placed on the open and flat-roofed house-top of mud plaster, rarely ascends above 112°, and at this season the canopy over head is curtained with light clouds, that happily protect the city from the too scorching beams of a tropical sun."—*Vol.* 1, *page* 6. That such clouds, and the air charged with steam with which they are intermingled, are generally raised daily by the sun, may be asserted from a knowledge of the causes that are in operation. And an observer, alive to the subject, would be as capable, there is no doubt, of tracing them, as an individual on the flat shore of Lancashire can trace the rise of the morning mist, from the surface of the Irish Sea, to a considerable height, where it forms a cumulous cloud, and falls in rain, or dissolves in the evening, according as the amount of condensation is great or small. And, admitting that air, with abundance of steam, is thus raised, and condensation takes place over Peru, it will follow that other air from the west must flow to supply the place of that which has ascended, and a sea breeze must blow. This breeze ceasing at night, is a consequence of the sun no longer raising the lower part of the atmosphere. When the causes in operation are sufficiently powerful to produce copious condensation on such a coast as that of Peru or Chili, much rain falls, and the sea wind is constant, or blows by night as well as by day, as it does on the coast of Tierra del Fuego. But when the action of the sun on the surface of the land is necessary to heat the air immediately adjoining the land, so as to raise the air, and thus produce condensation—as soon as that action ceases the ascending current ceases, and with it the sea breeze which constituted its supply.

We are then warranted in coming to the conclusion that there are no sea breezes on the western coast of Northern Africa, and other parts that have been named which are similarly circumstanced, although the sun is sufficiently powerful in those places to heat the lower air and make it rise, because there is not sufficient steam in the air to allow condensation to take place to that extent which shall produce an adequate ascending current. It being condensation that gives power to the ascending current, where that is absent the current is so feeble as to be scarcely felt, or in any way traced, though it may be evident that some portion of the lower air does rise. It may be that there are small ascending and decending columns of warm and cool air in the same locality, producing that tremulous motion which has been often observed, and acting in such a way as not materially to disturb the adjoining region over

the cool sea, and, therefore, no sea breeze is experienced. But when there is sufficient steam to produce an ascending current, then the current may, and probably does, become an ascending mass, extending over a considerable space, without having any small descending streams within it. And the supply of air that is required to restore the equilibrium of atmospheric pressure must come from an adjoining lower region, and that region being the sea a sea breeze is formed.

That condensation, to a considerable extent, does take place along the west side of the Andes, in Peru, at that time which seems requisite for the creation of the sea breeze, is known. SMITH, who visited the interior of the country, states that—"During the dry season on the coast the rains are experienced in the interior of the country, and lofty range of the high land, especially in the months of January, February and March, when the rain that falls inland is often very heavy, and on the most elevated regions it is not unfrequently alternated with snow and hail. Thus the dry season of the coast is the wet in the Tierra, or mountains."—*Vol.* 1, *page* 11.

Although but little rain falls on the low grounds of Peru near the sea, it appears, from facts given, that the dew-point must be tolerably high in the northern part. But as the southern wind, that prevails in this quarter, proceeds towards the equator, it has its temperature progressively increased, and will, therefore, not be inclined to condense steam, unless some material disturbing cause should interfere. This wind blows along the low land of Peru, and over the adjoining sea, and seems to be disturbed only by the daily action of the sun, which, by raising the lower part, commences condensation. At that part of the coast where there is the least steam in the air, and the greatest difference between the dew-point and the temperature, there will be the least condensation by the daily raising of the lower air, and the least sea breeze. As the general wind advances towards the equator it takes up more steam by evaporation, the dew-point rises, and any adequate disturbing cause, which may then come into operation, will produce a larger amount of condensation and a brisker sea breeze. And along the whole coast the strength of the sea breeze will be proportioned to the extent of the condensation that takes place over the land. This accounts for what we are told by Captain FITZROY, who says that—"To the northward of Callao the winds are more to be depénded on, the sea breeze sets in with greater regularity and fresher than on the southern parts, and near the limits of the Peruvian territory a double-reefed topsail breeze is not uncommon."

The causes which produce sea breezes along this coast are in full operation at Panama. The Hon. P. S. SCARLETT, in his book on South America, says, when speaking of Panama—"May 17. It pours with rain five or six hours in the day, and the thunder and lightning are awful. The rain generally begins at eleven o'clock." —*Vol.* 2, *page* 212. Here we see that rain falls about the time that the sea breeze sets in strongly along this coast, and if no condensation was going on in this part but that which produced this rain,

it must have produced a strong sea breeze. Further to the north of the line, along this coast, we learn that similar winds blow.

We have seen that no regular daily sea breeze existed along the western coast of the Sahara, or North African desert, although the land is there very hot—yet to the south of that desert a sea breeze prevails. Lieut-Col. SABINE says, when speaking of Sierra Leone—"About ten or eleven the sea breeze commences, usually in the north-west, freshening and becoming more westerly as the day advances." "Towards the evening the sea breeze dies away, and the land wind gradually springs up."—*Daniels, page* 318. Thus, in that quarter of the world we find that there is no daily sea breeze near to the hot desert, whilst there is one at Sierra Leone! But the country about Sierra Leone is mountainous, and, as the dew-point is commonly high, condensation may, and it is to be presumed that it does, take place daily among the mountains, as we have seen it does among the mountains of South America.

Sea and land breezes are found in islands as well as on the shores of continents. In the 7th vol. of Captain Cook's Voyages it is stated that, when at the Sandwich Islands—"In the harbour of Karakakooa we had a constant land and sea breeze every day and night." And the accompanying circumstances attending these breezes are given as follows:—"We generally saw clouds collecting round the tops of the hills, and producing rain to leeward, but after they are separated from the land by the wind, they disperse and are lost, and others succeed in their place. This happened daily at Owhyhee, the mountainous parts being generally enveloped in clouds, successive showers falling in the inland country, with fine weather and a clear sky at the sea shore."—*Page* 108.

MALTE BRUN, who collected information with great diligence, says generally of these islands—"The South Sea Islands, notwithstanding their small circumference, in this manner, as in a sea breeze, during the day time attract the general east wind, which is thus made to embrace them, as it were, on every side, and to blow from all points of the compass towards the central summit of the island. When night arrives the air flows back again, from the summit towards the sea, in every direction."—*Vol.* 1, *page* 385. The lofty summits of the mountainous islands of the Pacific are known to be cool, and they are seen covered with clouds, which must, to a considerable extent, obstruct the sun's rays—how then can they be sufficiently heated, by the direct rays of the sun, to produce the sea breeze that blows during the day? Only one conclusion seems left, which is, that if the sun has acted, it was merely as an intermediate agent, and displayed sufficient power to cause condensation to commence, and that that condensation produced an ascending current and a sea breeze.

If this conclusion be erroneous, it may, no doubt, be easily shewn to be so, as, according to the theory here advanced, the sea breeze must be always accompanied by the formation of a cloud. And if it can be shewn that regular intermitting or true sea breezes exist without cloud having been formed, it will go far towards shewing

that the theory is fallacious. It is not for one who has had to collect his information principally from books to say that no such instances can be pointed out, as that would be an assertion of a negative, not founded on information but opinion, and such an assertion would, therefore, be improper. But it appears, from numerous accounts of these phenomena, that sea breezes are always accompanied by an atmosphere pretty fully charged with steam; and the breezes are the strongest where the charge of steam is of a certain height. It is within the tropics, whether on the coasts of continents or islands, where the dew-point is high, that sea breezes principally prevail. And beyond the tropics, where they are found, a high dew-point for the locality exists. MALTE BRUN says they prevail on the coast of Norway, and there seems to be a higher dew-point about that coast than in any other northern part in nearly the same parallel of latitude. Tropical steam is carried to the coast of Norway, and if, during the summer, the sun, in the day, can raise the lower part of the atmosphere so much as to commence condensation, a day cloud and sea breeze may be produced in the part. But if daily sun-heated land were the sole cause of the sea breeze should we find it only in Norway, in a high northern latitude? That country is known to be generally screened by clouds in the day time during the summer, compared with the coasts immediately south of it, and, therefore, cannot have its land heated in a superior degree by the direct rays of the sun; and yet regular sea and land breezes are not felt in the European countries south of Norway. The north-west part of France is heated by the sun during the day, and it cools down to a rather low temperature at night, and yet, when no day clouds are formed, regular alternating sea and land breezes are never experienced.

In the *Colonial Magazine*, in an account of the island of Martinique, we have the following statement respecting it:—"The heat is moderated every day by two regular breezes, one, which lasts from the rising to the setting of the sun, called the sea breeze—the other, which begins at seven in the evening, and blows during the greater part of the night, is called the land breeze. The humidity of the atmosphere is excessive. In the course of three successive years the hygrometer of Saussure has given, as the two opposite extremes, 100—60, and for the mean term of the humidity of the atmosphere of the isle 87—7."—*Page* 316. It is very likely that the clouds and rain which produced the regular sea breezes might have been seen in Martinique as they were in Owhyhee, and the connection between them might have been exhibited more palpably, but no accounts of the kind are given.

That clouds form over flat islands, when circumstances are favourable, seems very probable. Captain FITZROY, in the plates contained in his book, represents them as suspended over the low lagoon islands of the dangerous archipelago; and he speaks of the singular interruptions to the trade wind that occur in these islands. He says—"Not only does the eastern wind often fail among them, but heavy squalls come from the opposite direction." "This is especially the case from November to March." This is the time when evapo-

ration has the most fully saturated the atmosphere with steam, when the dew-point will, consequently, be high, and condensation the most likely to commence, upon any partial heating of the lower stratum of air taking place. That clouds do form in these parts is apparent from what is stated a little further on, where it is said that—"The islands of the dangerous archipelago have no hill or height of any kind about which clouds, attracted by them, taken together, can gather and discharge a portion of their contents, electrical, as well as fluid. It may, I think, be inferred, that the want of such a conductor as would be furnished by a mountain 5,000 or 6,000 feet high is the reason why clouds, in various electrical conditions, unite or oppose one another, as the case may be, and, in consequence, cause rapid changes in the atmosphere around them, of which the effects are seen in squalls, sometimes with heavy rains, sometimes without, and even in whirlwinds."—*Page* 507. Whatever may be thought of the theoretical part of this passage it seems tolerably evident that the atmosphere was here occasionally disturbed and clouds formed, and squalls, heavy rains, and whirlwinds produced. It does not appear, from the account given, that there was that regular sea breeze prevailing here which is found in many other parts, but the information is not sufficiently full to enable an opinion to be formed on the peculiarities of the case. With our present amount of information, all that can be said seems to be that these small flat coral islands disturb the moist atmosphere about them, and that clouds, rain, and winds attend the disturbance.

But winds of the nature of daily sea breezes are not confined to the *shores* of either continents or islands. In the interior of Northern Africa, the great desert of Sahara is bounded to the south by a mountainous country, and in the flat country, near to the mountains, daily winds are found to blow, as they do in other parts on sea coasts. DENHAM says, in vol. 1, that—"The cool winds (in Bornou), which had prevailed for the last fifteen days, had so purified the air that disease appeared to be taking its departure, and a season of health about to succeed in its turn. These long wished for breezes generally came on about ten in the forenoon and continued until two hours after midday." Doubtless the morning sun raised the air sufficiently to produce condensation and create an ascending current, which took place among the mountains, when a daily wind from the hot plain blew towards the mountains to supply the place of the raised air, producing a daily breeze in a part very remote from the sea, but which came from the hot land to the comparatively cool mountains.

From the foregoing facts and reasoning we are, it is conceived, justified in inferring that daily sea breezes are not consequences of air, heated by the surface of land, rising, and admitting other and cooler air from the sea to flow into the comparative vacuum thus made, but that these breezes are results of condensation of atmospheric steam, which, in each instance, produces an ascending aerial current that causes the flow of the adjoining air into the vacuum. And in the absence of the sun the air, which had been warmed by the condensation of steam, becomes cool and flows back—thus producing daily alternating sea and land breezes.

ON

UNEQUAL TEMPERATURE AT CERTAIN HEIGHTS IN THE ATMOSPHERE.

When ascending currents flow against the sides of mountains, condensation taking place during the ascents, it is apparent that the currents will take the heat which is liberated with them to some certain height, and in the locality produce a temperature higher than generally belongs to the latitude and elevation; and if the cause of the ascending current is of a permanent nature, the general climate of the part will be modified accordingly. An effect of this kind, it is presumed, is produced in the region of great condensation near that part of the tropical Andes already adverted to, although we have no particular account of it. HUMBOLDT, however, mentions a fact which illustrates the point: he says that when they were going over the Pass of Quindihi, 11,499 feet high, and in the latitude of 5° north, rain fell *heavily*. Now as the rain *fell* at that height it must have been previously carried or generated still higher, but in an atmosphere unaffected by particular influences, rain could not be formed at so great a height, and if carried thither would be converted into hail by the cold which ordinarily exists at that elevation.

But a more striking instance of warmth of climate, at a considerable elevation, being produced by condensation of steam, is given by ARCHER, in his travels among the Himalaya mountains. When speaking of a part among these mountains, in about 31° of latitude, he says—"The limits to the cultivation of corn vary, but the maximum elevation is estimated at 13,000 feet, a point which theorists have buried deep under perpetual congelation." According to LESLIE the height of perpetual congelation, in this latitude, is 11,253 feet. But these theorists were not aware of the influence of condensation in warming parts at great heights. To ripen corn at the elevation named required not only that the heat should be carried to a great height, but that it should be so constantly taken thither as to enable the crop of corn to grow and reach maturity! DALTON says—"Every habitable latitude enjoys a heat of 60° at least for two months, which heat seems necessary for the growth and maturity of corn," *page* 124; and HUMBOLDT says, that in the island of Teneriffe, in 27° north, the highest point for the growth of wheat is only 1,300 feet, or just one-tenth of the height at which corn grew on the Himalaya!

Elevated ridges of land and mountainous islands, up which masses of air are impelled by adequate causes, are then important instruments in effecting condensation of atmospheric steam, and determining the climates of various parts. But geologists tell

us that the land which is now elevated has not been always in that state. Supposing such opinions to be correct, it will follow that there has been a period when that condensation, which now, in many parts, makes the particular localities wet and warm, did not take place in those parts. There has been a time, we must presume, when the Himalaya mountains did not rise above the level of the sea, and consequently did not cause Hindoostan to be wet and warm! DARWIN and others suppose that the continent of South America, speaking geologically, has been recently elevated, and consequently it will only recently have condensed that steam which, brought from the Southern Pacific, now determines the peculiar climate of the south-west coast of that country. The mountains of Central Africa being supposed to have been, at some time, raised above the level of the sea, it will follow that, prior to that raising, the west winds of the coast of Guinea, the Ethiopian rains, and the periodical rising of the Nile, did not exist! When Norway and the British Islands were beneath the sea the part of the globe which they occupy may not have been as it is now, wet and warm for the latitude. And those parts which are now so elevated may possibly again sink, and produce changes of climate in their localities. Should the mountains of Central Africa subside, the steam which is now periodically condensed in that part of the world might pass on to Arabia and Persia, and make those countries moist and rainy, instead of being arid, as they now are. The Himalaya mountains and Central Asia, being supposed to sink, the steam now intercepted by them would pass on to Siberia, and make that country wet and warm compared with its present state. The geologist may conceive ridges of mountains to have existed where now we see only small groups or chains of islands. If the line extending from the Atlas mountains, in Africa, by the Azores, to Newfoundland, was ever sufficiently elevated to arrest and condense the steam which passed from the tropics about the West Indies, the consequence must have been that the British Islands and Norway would be left with a climate as dry and cold as that of Siberia and Northern Canada. Thus we see that the elevation of one part of the surface of the globe and the subsidence of another, which geologists say have taken place from time to time, may cause important alterations in the climates of the parts.

DANIELL gives some facts respecting steam at a considerable elevation. He says that Mr. GREEN, when in a balloon—"At an elevation of about 9,890 feet, found the dew-point at 64°, exactly the same as I ascertained it to be at the surface of the earth. At 11,060 feet it had fallen to 32°." Colonel SABINE ascertained that —"At Sierra Leone the dew-point of the vapour at the level of the sea was 70°, and it was the same, at the same hour, upon the summit of the Sugar-loaf Mountain, 2,520 feet above." "At Trinidad the temperature of the air at the level of the sea was 82° and the dew-point 77°; 1,060 feet above they were both 76°—5', and precipitation was going on." "At Jamaica, by the sea side, the temperature of the air was 80° and the point of deposition 73°, while on the mountains, at the height of 4,080 feet, they were both 68°—5'.

At a station not five hundred feet higher, by experiment twice repeated, the point of deposition was found to be 49° and the temperature of the air 65°."—*Daniell's Essays, page* 119. In all these cases steam had, doubtless, ascended and formed cloud, and the liberated heat kept up the temperature. DANIELL gives also the following from DE LUC's observation on a mountain—"Pendant que je réfléchissois sur l'apparition subite des nuages, je découvris un petit amas de vapeurs, du côté du nord, à 3 ou 400 pieds audessous de moi: Je le considérois avec attention, et je remarquois d'abord que son volume augmentoit sensiblement, sans qu'il me fût possible d'appercevoir d'où lui venoient ses accroissements. Je vis ensuite qu'au lieu de s'abaisser à mesure qu'il grossissoit, et qu'il paroissoit même devenir plus dense, il s'élevoit au contraire. Le vent le poussoit vers moi. Il m'atteignit enfin, et m'environna tellement que je ne vis plus ni le ciel ni la plaine. Je pensai au même instant, à observer mon thermomètre qui étoit suspendu en plein air, éxposé au soleil et que j'avois vu auparavant à 42°. Je présumois que l'action du soleil étant interceptée par ce nuage mon thermomètre devoit baisser et je fus très surpris de le voir au contraire à 45°. Le nuage, qui continuoit à monter obliquement vers le sud, abandonna bientôt le lieu où j'étois, le soleil reparut, mais, malgré son action, le thermomètre rédéscendit."—*De Luc, tom.* iii, *page* 251. The higher temperature was, doubtless, produced by condensation, and that gave the buoyancy which caused the ascent of the cloud. It is rather surprising that facts like these did not lead inquirers into the right path of discovery.

It is sometimes said that contiguity to the sea causes coasts to be wet and warm, but this does not accord with numerous facts. The *island* of Newfoundland is in latitudes from 47° to 50° north, the same as the middle of continental France, yet the former place is thus described in a popular geography:—"In winter the cold is excessive, nothing but snow and ice being seen, and the bays and harbours being entirely frozen." And in Quebec, in the latitude of 47°, the temperature sinks to 32° below zero! in the winter. The coast of Labrador is in say between 50° and 60° of latitude, but the cold of winter is intense compared with that of the British Isles and Norway. And, according to PEROUSE and others, there is as great a difference, in the same latitudes, in parts equally near the sea on the east coast of Asia and the west coast of America. These differences all result from the eastern coasts not being warmed, as the western are, by the condensation of steam against elevated land. Yakutz, in Siberia, is said to be the coldest part on the continent of Asia, having sometimes a temperature of 90° below freezing; this place is 130° east of London, and of course the same distance from the Atlantic Ocean. But at Fort Reliance, on the great Slave Lake, about the same latitude, in North America, Captain BACK found a temperature of 102° below freezing, yet that place is only about 30 degrees from the coast of the Pacific, it, consequently, is 100° of longitude nearer to the ocean on its west side than is Yakutz. But in America the steam from warmer latitudes had been more decidedly intercepted and

condensed, by mountains, than it had been in Asia. It is the high ridge of the rocky mountains that forms the barrier between the warm climate of the western coast of America and the intensely cold one of the eastern parts. Such a complete barrier does not exist in Asia, the northern part of which is, to some extent, warmed by the steam from the Atlantic.

ON THE CONNECTION OF ATMOSPHERIC CURRENTS.

The various atmospheric currents which we have passed under view have been treated as separate currents—but it is not to be supposed that they should be considered as absolutely separated from each other. The probability is that every such current is disposed to move forward and form a fresh current, and thus produce a general circulation of the atmosphere. But those which have been distinguished by separate names have been so far modified, by local influences, as to give each of them, in the lower region of the atmosphere, a particular direction and character, and they have been treated separately, as lower currents, in order to show their connection with the local influences Yet in some of them the marks of separation are not very palpable, and on further inquiry it may be found that what we have treated as two currents may be only one. Captain Basil Hall says that in the southern hemisphere, in the latitude of about 40^{0}, a west wind blows all round the globe. And it may be that the islands of Van Dieman's Land and New Zealand merely lie in the path of this wind, and do not separate it into two currents. This, however, would only oblige us to say that the current which left the tropical region in Brazil proceeded to the parts named, and forward across the Southern Pacific Ocean to America, as one current, instead of speaking of one terminating at New Zealand and another at America. And it possibly may be that some connection may exist between the western wind that blows on Cape Horn, and that which crosses the Southern Indian Ocean to New Zealand, but the facts given by voyagers afford less countenance to this supposition than to the former one. A moderate south-east wind appears to blow near the eastern coast of Patagonia, which would cross the path that would have to be traversed by a westerly wind passing from Cape Horn to join that which crosses the Southern Indian Ocean. In the present state of our knowledge, then, this appears to be a break in the general west

wind, which Captain B. Hall says blows all round the globe in the latitute of about 40° south; and the break appears to be attributable to the great condensation of steam in the neighbourhood of Cape Horn. In the northern hemisphere more disturbing causes exist than in the southern. The mountains of the British Islands and Norway seem to draw on the Atlantic return current, and cause it to terminate about Norway, although a part of it evidently proceeds farther on to the icy sea. The south-west monsoon of the Indian Ocean terminates principally against the lofty ridge of the Himalaya mountains, but it is not unlikely that a part of this wind proceeds over the China Sea northward as far as the Japan Isles, and then turns westward across the Pacific to the American coast, along which we have seen it spreads, though it does not pass the mountain-ridge, which runs nearly parallel with the coast. It may then be that the Japan Isles, at certain times, have sufficient power, arising from the condensation which takes place over or near to them, to divert or bend, or partially to arrest the western return current that is disposed to pass near to or over them, without being able entirely to absorb and thus terminate it, as a lower current in their locality, as the more lofty Himalaya and American mountains do in their particular districts.

Captain Basil Hall, in a letter to Mr. Daniell, inserted in his essays, when speaking of the North Atlantic eastern trade wind, has this passage:—"As the ship advances to the southward she finds the trade wind drawing round gradually from east to north-east, and finally to north-north-east, and even north at the southern verge of the north-east trade." And he afterwards states that, on first meeting the eastern trade of the *South* Atlantic, it "does not blow from the east, as the navigator is led to expect, or in a direction parallel to the equator, which would be to him a fair wind, but it meets him, as it is emphatically termed, *smack in the teeth.*" And, subsequently, the captain attempts to account for these north and south winds near the equator in this way. He says, speaking of the north-east trade—"As this cool air, however, is drawn nearer to the equator, and comes successively in contact with parallels of latitude moving faster and faster, this constant action of the earth's rapid easterly motion gradually imparts to the superincumbent air the rotatory velocity due to the equatorial regions which it has now reached; that is to say, there will be less and less difference at every moment between the easterly motion of the earth and the easterly motion of the air in question; while, at the same time, the other motion of the same air, or that which has a tendency to carry it straight to the equator, having been exposed merely to the friction along the surface without meeting any such powerful counteracting influence as the earth's rotation, will remain nearly unchecked in its velocity. Thus, as I conceive, the trade wind must gradually lose the eastern character which it had on first quitting the temperate for the tropical region, in consequence of its acquiring more and more that of the rotatory motion of the earth, due to the equatorial regions it has now reached."—*Daniell's Essays, page* 482. If

the influence here pointed out were the cause of the east wind ceasing to be such, and becoming north and south winds in the Atlantic, the same phenomena would occur, in a more palpable manner, in the Pacific Ocean, seeing that the eastern wind of that ocean has a much greater range of longitude in which it may acquire the full rotatory velocity of the earth, and it would, therefore, more decidedly lose its eastern character. But the east wind of the Pacific blows steadily over the whole extent of that ocean. Condensation, on the opposite continents of Africa and America, probably affects the Atlantic atmosphere so as to produce the peculiar effect described by Captain Hall.

Among the various currents of which we have treated it has been found that some moved parallel, or nearly parallel, to each other, but in opposite, or nearly opposite, directions—this is most palpably the case in the wide and open range of the Pacific Ocean. The eastern trade wind appears, at times, to extend from tropic to tropic, and the western return currents are said to touch on the 40th degree of latitude in each hemisphere. But the limits of these currents may, from the causes known to be in operation, be presumed to vary with the seasons. In the summer of the southern hemisphere there will be more steam formed and condensed on the south side of the equator, and in the summer of the northern hemisphere on the northern side, and the western return current will, in each hemisphere, no doubt, extend its limits at that period when it is furnished with the greatest power. The islands which lie in the path of the eastern trade wind will, also, have their disturbing and modifying influences, according as condensation takes place more or less freely among them. But notwithstanding all these disturbing causes, it appears that, between the ordinary, though varying, limits of the eastern trade wind and each of the western currents, there is a space in which neither wind decidedly prevails. This line or stripe may, with reference to our present subject of inquiry, be considered as belonging to the region of calms; not because it is absolutely calm, but because neither the one nor the other of the adjoining great atmospheric currents predominates in it. This stripe is, by navigators, represented to be generally cloudy or misty, and to have not unfrequently rains and varying winds, weather that might be supposed likely to prevail from the causes that are known to be in active operation in the neighbouring parallels. Such a region of calms is said to exist about each tropic in the Pacific Ocean. One is also found in the Atlantic, between the north-east trade wind and the south-west return current. And such an one exists, in tropical parts of the Indian Ocean, between the south-east trade wind and the north-west wind that blows from the Indian Ocean towards the islands of the East Indian archipelago, and is spoken of by Cook. These regions of calms have been avoided by navigators, excepting when they had to cross them, and, consequently, they have seldom given many particulars respecting them. But it is not unlikely that, in each of these parts, the neighbouring atmospheric current, which is fully charged with steam, will overflow from the effects of

condensation of a part of that steam, and in this way furnish a regular supply of air to the adjoining space. The region of calms must itself be liable to have a full charge of steam, particularly in a warm latitude, as evaporation will be disposed to continue up to the furnishing of the maximum quantity, when any disturbance will be likely to produce condensation.

In addition to these lines of calms there are particular localities which may be considered regions of calms; yet these regions are not, as the name may seem to imply, absolutely calm, but in them no particular wind prevails. Calms are there common, but they are broken in upon by sudden storms, and, during these storms, the wind blows from any, and sometimes from every, point of the compass. One of these regions is in that part of the Atlantic which is within the tropics, and it extends along the coast of Africa. Excepting when west winds blow in the Gulf of Guinea this region has no regular wind: here evaporation goes on until the atmosphere is nearly saturated with steam, and the neighbourhood of the Gulf of Guinea is known to be one of the most unhealthy, and of the least favourable for navigation, of any region of the globe.*

Another of these regions of calms is found in and near the Gulf of Panama, not far from the equator, and the kind of weather experienced in this part is graphically described by the Hon. P. C. Scarlett. He says, on April 19th—"We are now becalmed, and in the worst part of the world, three degrees north of the line. A heavy oily swell, a gloomy sky, spongy clouds, the ship creaking, sails flapping, and all hands longing for a change. Then the drowsiness caused by this temperature (very hot) is quite overpowering. I am sure a week of probation like this would injure the strongest constitution, such is the debility and loss of energy which it occasions."—*Page* 175. These two regions lie near the equator, immediately to the west of the two continents of Africa and America, and these continents intercept the eastern currents which, in other parts, flow along within the tropics. But though there are no regular lower horizontal currents in these parts of the world, we are not to conclude that the same masses of air remain constantly in them: this would be contrary to the general laws which govern the atmosphere, which laws produce motion and change, to a greater or less extent, every where. The air in these regions of calms being pretty fully charged with steam, and heated by a tropical sun, must have a tendency to rise and expand at some certain height, and a fresh supply must flow in below from surrounding parts, though not with sufficient strength to constitute a wind. And the sudden storms or tornadoes, as they are generally called, which take place in these parts, must be effects of local, rapid and considerable condensation,

* "The great difficulty of the outward-bound voyage commences after the ship is deserted by the north-east trade, as she has then to fight across a considerable range of calms, and of what are called the variables." And in the homeward-bound voyage the same writer says—"After reaching three or four degrees of north latitude, the ship will lose the south-east trade, and re-enter the variables."—*See Captain B. Hall's Letter in Daniell's Essays, page* 470.

and must, therefore, be presumed to produce ascending currents in the particular places, creating irregular and temporary disturbances, both in the upper and the lower regions of the atmosphere.

In these regions of calms the dew-point is generally high, say, between 70° and 80°, and they constitute some of the most unhealthy localities that are known. Indeed, what is called malaria seems to prevail more or less wherever the dew-point rises above 70°, whether it be over land or sea. And even when it is somewhat lower than 70°, a certain degree of malaria is common, which produces marsh fevers and agues. But when the steam which gives the high dew-point is condensed, and falls as rain, or a dry wind sets in, the virulence of the malaria is abated, or it entirely ceases. The uniform coincidence of a high dew-point with malaria fever suggests the idea that they may have the relation of cause and effect; and it may be well to consider whether that fever is not produced by a disturbance of evaporation from the lungs. See a paper printed in the *Philosophical Magazine*, for February, 1830, "On malaria."

ON DESCENDING WINDS.

Ascending aerial currents, produced by condensation of steam, have been shewn to be important agents in creating and continuing the great horizontal currents of the atmosphere. But the air of these ascending currents is not heaped up in the localities in which they exist. The state of the barometer shews that, so far from there being more air in the parts where they are found, there is generally less, consequently, that which ascends must readily expand, spread out, and diffuse itself around. Now it is very desirable that these expansions and spreadings should be traced, and the effects they produce be noted; and though our knowledge of what takes place in the higher regions of the atmosphere is very imperfect, yet scattered facts, when brought together, may enable us to obtain some perception of what is going on in this obscure department of nature's works.

It has been already shewn that the theory which teaches that the heated air of the tropics rises and flows over in the higher regions of the atmosphere, towards the poles, is not universally true. Indeed it appears to be rather the exception than the rule, as the various western currents on the surface of the globe that have been traced sufficiently prove. The fact, however, that the heated air of the tropics does not universally, nor even generally, return to the poles in the higher regions, has, it is conceived, been sufficiently established. But what are the particular causes which determine that the air

which had been heated, and carried to a certain height in the atmosphere, should, in an adjoining part, descend, and become a lower current, as we have found it does. If we suppose that the raised air is heaped upon the adjoining air, it will press into it, and cause it to spread, and this would produce a wider expansion in the middle regions rather than a descent to the lower. The warmed air itself would, however, obviously have a tendency to expand and flow, in the higher regions of the atmosphere, towards the poles; and the cause of its frequent descent to the lower region must be sought in some other operation of nature.

In examining the phenomena attendant on ascending aerial currents, the most striking seems to be the production of rain by the condensation of steam, the quantity of rain produced being proportioned to the amount of condensation. Over the sea within the tropics, and in some other parts, when the atmosphere is undisturbed by any powerful cause, the rain produced by condensation is small, forming merely a mist, and making the weather cloudy or hazy, and the mist descends to the earth with a slow motion. But where there is sufficient steam, and an adequate disturbing cause, a powerful ascending current is produced, and more copious rain is the result. The small particles of water first formed in the ascending current will be carried up with the stream of air, and coming in contact with other particles they will unite and form globules, or round drops. And the greater the height to which the rain is carried, and the more complete the disturbance and turmoil within the current, the larger will be the drops. As we suppose the current to expand in the higher regions, it would carry the rain with it in its expansion, until the force of gravity overcame the carrying or suspending power of the current. The rain would now begin to descend, and as the larger drops would fall with the greatest rapidity, they would strike against and unite with the smaller, until, on approaching the earth with accelerated speed, they would be of a size, and fall with a velocity proportioned to the height from which they had descended, and the thickness of the cloud through which they had passed.* When warm rain falls it would seem that it must have been not only produced in the interior of an ascending column where the air was warm for the elevation, but it also must have descended through a mass of such air to the earth. Whilst any rain which, by the ascending and expanding current, should be violently thrown beyond the range of the warmed current into cold air, would be likely to reach the earth as a cold rain. Where the rain was carried up to a great height and then thrown off to adjoining very cold air, the drops might be frozen, when they would descend in the form of hail. But it would be impossible for myriads of drops of rain or hail to fall in this manner without bringing with them much of the air by which they were surrounded. If this reasoning is correct, it will follow

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* "A drop of the twenty-fifth part of an inch, in falling through the air, would only gain a celerity of 11½ feet, while one of a quarter of an inch would acquire a celerity of 33½ feet."—*Leslie.*

that whenever rain or hail falls from a considerable height in the atmosphere it must bring with it more or less of air from the higher regions. And if the process just described be supposed to continue, there would be a continued descent of air, and the process taking place over a sufficient extent, there would be, in that space, a bringing down of the higher parts of the atmosphere to the surface of the earth in such a way as to produce palpable local effects on the mass of the atmosphere.

Does not this accord with what is experienced in many places? Sailors say that a heavy rain or hail "lays the sea." The fact, no doubt, is, that the descending air counteracts the effect of the horizontal wind which raised the waves. When heavy rain falls suddenly it always brings wind with it. It is common to say that the wind brings the rain, but that form of speaking equally expresses the fact that the two come together. And if what has been advanced respecting the manner in which rain is produced is true, it is only an acending current of air that can produce heavy rain, and carry that rain up with it. In afterwards descending from a height the gravity of the rain must be the active cause in operation, and that cause produces the effect of which we are speaking, the descent not only of the rain but of the air that was intermingled with it. When partial but heavy showers of rain are seen in profile from a favourable situation the rain may be often seen descending from the cloud in which it has been produced, and we may infer that the rain carries with it a part of the air which it encounters. And, under such circumstances, the wind in the part is invariably found blowing in the direction indicated by the fall of the rain. Indeed the whole may be witnessed occasionally at sea in one view. From a ship's deck the rain may be seen falling and the wind blowing against the sails of other ships, or carrying smoke in the direction of that fall, although a calm may exist in contiguous parts, or the general wind may be blowing moderately in a different direction. The inference to be drawn from observing such phenonena is, that the rain descended by its gravity and carried the air with it, and the air, when it reached the earth, moved forward in the direction given to it by the rain, until its acquired force was expended.

When a current of air fully charged with steam reaches such a part as the West India Islands, and is there caused to rise and flow over in the higher regions of the atmosphere towards the pole, the rain which is there formed may, in its descent, bring air down to the surface of the earth. And this operation taking place over a wide space, the upper aerial current would, in its descent, force away the lower air and occupy its place. The north-east trade wind blows over a part of the West India Islands as well as towards the Andes, and those islands appear to have the power of condensing atmospheric steam and bringing down rain; and among them the process described may, and probably does, take place, which brings down the air that might otherwise be an upper current, and makes it become a lower current. In the southern part of the Caribbean Sea the dew-point is represented as being as high as 80°, and copious

condensation is likely to take place in that part of the world when disturbing causes come into action. The dew-point continues high in the direction of this aerial current, as it moves towards the north-east, yet in the southern part of the United States it is seldom found more than 75°, the current must, therefore, have parted with some of its steam in the formation of rain. From this part, across the Atlantic to the north-west coast of Europe, rain falls abundantly, and the dew-point is proportionately reduced, until, on reaching the British Islands, it is seldom above 60°. In Norway it is lower, and in both these parts rain falls freely, particularly against or near to the south-west sides of elevated lands, up which the current is forced by its inertia; and these localities are, in the autumn and winter, warmed by the large amount of condensation that is produced from this south-west current. Thus, there will be found along the line named, frequent ascending currents producing rain, and the rain, when formed, bringing down the air with it, keeping the whole atmosphere, in the part, more or less in a state of turmoil and agitation: and the high lands of the western sides of the British Islands and Norway, by the great condensation which they cause, and the comparative vacui which they produce, whilst they increase the agitation, tend to draw this south-west wind, as a lower current, from the tropical regions towards themselves. In the return current, which proceeds from Brazil to New Zealand, the same peculiarities are obervable as those seen in the Northern Atlantic. Captain FITZROY says, that "at Rio de Janeiro, in summer, thunder storms often occur." "Gales, in the latitude of Santa Martha, generally commence with north-westerly winds, thick cloudy weather, rain, and lightning. The climate is unhealthy in December, January and February, and during the whole year there is a deal of rain."—*Page* 84. From this part of the Brazilian coast the north-west wind blows as far as New Zealand, and it retains its character throughout the whole extent, as it is rainy and much disturbed. We have seen that Captain B. HALL says that getting into this current is advantageous in order to proceed east, but it is "at the expense of some discomfort, for the weather is generally tempestuous." Now, as that is the case, there must be much condensation of steam, ascending aerial currents, formation of rain, rushing in of air below, and descending wind produced by the fall of rain: in short, all that kind of disturbance which we presume attends the progress of a tropical current, highly charged with steam, in its passage to a cooler region. In the two return currents of the Pacific Ocean similar disturbing causes exist, and weather of a similar character is found to prevail.

As an ascending aerial current, which reaches a great height, must condense nearly the whole of the steam intermingled with it, should the whole mass afterwards descend, the air must descend without the steam that it previously contained. And should the air in the neighbourhood of a locality where great condensation is taking place be found very dry, it may be inferred that it has had a large part of its steam condensed by having been carried up to a great height, at

which height rain was formed and fell; the air, or a part of it, proceeding on to another part, where it descends as a dry air. This is a point that has been but little noticed by observers, but it has been incidentally mentioned. In KING and FITZROY'S Voyages, it is said that, in a part near Cape Horn, of which we have already spoken, where much rain fell, one inch of water evaporated in twenty-four hours. Such rapidity of evaporation is incompatible with a high dew-point at the same time and place; it may, therefore, be concluded, that at the time of this evaporation the dew-point was low; yet it was in the same district in which it is stated that twelve inches of rain must have fallen in the course of thirty days. This then is an instance of a dry atmosphere being found, that is, an atmosphere with but litttle steam in it, when all around much rain fell. The dry air, it is evident, could not have come from a considerable distance in the lower region, and we must, therefore, conclude, that it could only have come from the higher parts of the atmosphere which had been deprived of their steam by condensation.

To the east of the Andes, near the Caribbean Sea, is a locality in which the dew-point is generally high, sometimes as high as 80°, and in which condensation takes place very freely, as much rain falls; and yet here, in a particular place, HUMBOLDT incidently states that evaporation goes on rapidly, and there must, consequently, be a low dew-point, compared with the temperature. He says that, "at Cumana, the surface of the sea in the port generally ranges from 70°—3′ to 79°—3′, and the temperature of the air, in the season of the floods, is as high as 91°. But at Aroya there are extensive salt works, and evaporation is so rapid that salt is collected in eighteen or twenty days after the reservoirs have been filled." Now the general state of the atmosphere about this part is moist, it being highly charged with steam brought by the Atlantic trade winds, and the dry air of Aroya can, therefore, only be presumed to be an overflow from an ascended current that has had its steam condensed into rain, which brought down the air into this part of the lower region of the atmosphere.

I do not know what was the rate of evaporation at Aroya—HUMBOLDT appears to have thought it extraordinary; but for an inch of water to evaporate in twenty-four hours, as it did near Cape Horn, is surprising, when the low temperature of the part is considered; at this rate 365 inches of water would be evaporated in a year.

Although this degree of dryness of the atmosphere may be considered extraordinary, yet dryness, apparently from the same cause, and that, too, of a high degree, is not very uncommon, It is well known that, in many parts of the world, the dew-point is high at one time and at another comparatively low; and, under certain circumstances, the one state quickly follows the other. In the summer or autumn of our own country, when the atmosphere has been for some time stagnant, evaporation has proceeded until a large amount of steam has passed into the air, and the dew-point has become high, say 65°. But a thunder storm takes place, and the ground is deluged with rain; the storm is soon over, the weather

becomes clear and bright, and the air is said to be purified by the storm. But, under such circumstances, what meteorological alterations can be detected in the atmosphere? Why, much of the steam previously existing in the air has disappeared, and the dew-point has fallen from 65° to 60°, or perhaps to 50°, furnishing evidence, of the most convincing character, that a part of the steam which had previously existed in the atmosphere, in an aeriform shape, had been, by a sufficiently low temperature, condensed, and converted into rain. The air is now found comparatively dry, and evaporation goes on much more rapidly than it did before the thunder storm. Before the storm the air rather wetted than dried anything exposed to it, afterwards it dries rapidly, and is in a state approximating to that in which the air near Cape Horn permitted an inch of water to evaporate in twenty-four hours.

In Tierra del Fuego condensation takes place to a great extent, and with as much violence, as, if not more than, in any other part of the globe, and it is consequently the most likely place to find a large mass of dry air descending on a neighbouring part. And, accordingly, we find that in Eastern Patagonia the air is very dry. This country has been but little visited; some extracts have already described the dry and barren nature of the coast. But Captain Fitzroy has furnished an interesting account of an ascent of the river Santa Cruz. This account represents that, in the month of April, in the lower part of the river, the country was a dry desert, with the temperature below the freezing point. But as the travellers ascended the river, although they were not proceeding to a warmer latitude, and although the winter of that part was advancing, yet the temperature of the air rose, and they at last had clouds, some rain, and strong winds. When two hundred miles up the river the party found they were four hundred feet above the sea. When forty-five miles higher up they were thirty miles from the Cordilleras of the Andes, and the height of these mountains was (by a theodolite) from 5,000 to 7,000 feet above their level. It is sufficiently apparent, from these facts, that the country near the lower part of this river was dry because the air was dry, and as, at the same time, rain falls very abundantly in the Falkland Islands and in Tierra del Fuego, we may conclude that the air near the lower part of the river Santa Cruz had flowed over from the rainy and stormy regions of those two places. The upper part of the river is near a region of condensation, and seems to receive some of the rain which is the product of that condensation. The particular part where it took place must have been warm, as we find the water in the river, at a considerable distance, of the temperature of 46°, whilst that of the air was only 30°. The only fact that appears opposed to the view here taken is the coldness of the air in the dry part, but it should be borne in mind that such a capability of evaporating water as that exhibited in Captain Foster's rain gauge, where an inch was evaporated in twenty-four hours, would soon cool the air, and that too without sufficient moisture being taken up to destroy the dryness found near the lower part of the river. We are then at liberty to presume that

the air of the eastern part of Patagonia is dry, because it had been previously deprived of a large portion of its steam in the stormy regions about the Falkland Islands, or Tierra del Fuego, from the higher parts of which regions the air of eastern Patagonia had come.

The western part of Patagonia is another region of copious condensation. From extracts already given it will have appeared that for heavy rains and fierce storms this part is scarcely surpassed by Tierra del Fuego. It is possible that a part of the air, dried by condensation, about the mountains of Western Patagonia, may cross the Andes, and descend to the eastern plains. But there is another district that is supplied with dry air, which probably comes from this region of condensation. The rain and storms of this coast extend northward to the island of Chiloē, and even to a part of Chili, becoming more moderate in the latter part. But further north, along the whole coast towards the equator, to say about the fifth degree of south latitude, the air is sufficiently dry to prevent any considerable fall of rain on the coast, and through a large extent no rain falls. Yet there is a constant flow of air along this coast from the neighbourhood of the region of condensation and storms just named, though it does not come from the part near the surface of the earth. Now, may not the air from this region of storms overflow to the north, and, descending on the coast between the latitudes of 35° and 30°, flow from thence to the vicinity of the equator? The flow of air is here constantly from the south, and, from facts named, the dew-point must be low in the northern part of Chili. Both the temperature and dew-point appear to rise as the aerial current approaches the equator; until within a few degrees of the line rains take place. But the great mass of the aerial stream turns to the east and passes across the Pacific to the Indian archipelago.

As any one portion of the atmosphere readily acts upon other portions, according to the way in which each is modified by heat and cold, and the motion given to one part is propagated through another until the force is expended, every current will exert a certain force on adjacent parts, and were we acquainted with all that takes place in the great aerial ocean which surrounds the globe, we should be able to trace the separate force of each current, and shew where it had been expended. That part of the continent of South America in which the rivers Amazon and Oronoco take their rise, is a region of great condensation. The atmospheric steam is supplied from the north-east and south-east trade winds of the Atlantic Ocean, and a part of the atmosphere thus brought, we have supposed to have been turned round and converted into two return currents, which took a portion of the steam they contained to the west coast of Europe in the northern and New Zealand in the southern hemisphere. But still very copious condensation takes place near the Andes. On the Upper Oronoco, near Rio Negro, HUMBOLDT was told that, on account of the rains, the sun and stars were seldom seen, and that it sometimes rained without intermission for four or five months. The water that fell in five hours, on the first of May,

he found to be twenty-one lines in height. And the quantity of water here furnished to rivers seems to be much greater than in any other part of the globe. We are led, therefore, to presume that there must be an overflow of dry air from this part, as the air which ascends to produce all this condensation must pass somewhere. Yet there does not seem to be that immediate descent of a large quantity of air to the surface which appears to take place near to the southern extremity of America. In SCARLETT's account of this part of America it is shewn, that there is reason to believe that currents prevail in the neighbourhood of this part in the higher regions of the atmosphere, moving both east and west from the Andes. He states that the ashes from the volcano of Cosiquina floated in the air to Jamaica, and at the same time south-westward 1,100 miles; there must, consequently, have been aerial currents to take the ashes to these parts, so decidedly in opposite directions. The current which flowed to Jamaica is known to pass above, and in an opposite direction to, the north-east trade wind, but to what part did the other upper current proceed? May we not reasonably suppose that it proceeded westward, to feed that great aerial stream which, within the tropics, flows across the Pacific? I know not of any account of dry air descending into the Bay of Panama, yet such may be the case in the western part, or it may reach the surface of the sea farther to the west. An oceanic current moves from the bay to the Galapagos, whilst another comes from the south. Captain FITZROY says—"On one side of Albemarle Island the temperature of the sea, a foot below the surface, was at 80°, but at the other it was less than 60°." And, when speaking of the atmosphere, he says—"How different is the climate of the windward and leeward islands of this group! Here (to windward) we were enveloped by clouds and drizzling fogs. At Tagus Cove and James' Island (on the north side) a hot sun nearly overpowered us, while the south side of Albemarle, Charles and Chatham Islands were almost always overshadowed by clouds, and had frequent showers of rain." "The southerly trade or perennial wind is very moderate; the winds appear to be much lighter and more variable to leeward of the archipelago, while the current (oceanic) is considerably stronger."—*Page* 498. It is not improbable that the upper current, which brought the ashes 1,100 miles from the volcano of Cosiquina, may here reach the surface of the sea as a dry wind, and may form that clear atmosphere which is said to be found in the Pacific immediately north and west of the Galapagos. In this, as well as in many other parts, a knowledge of the state of the dew-point would be likely to throw light on the movements of the atmosphere.

Other areas of condensation, such as the East Indian archipelago, the Himalaya mountains, and the west coast of North America, must, we presume, discharge their dried air on neighbouring regions, but with our present information there is no sufficiently palpable evidence to justify an attempt to trace them.

Inequality of surface temperature must be a sufficient cause to produce, in the lower regions of the atmosphere, a slight general

flow of air from cold to warm climates; and the general condensation of steam in the low level regions of the tropics produces a similar result. These two influences are energetic enough to produce a slow general flow of the lower portion of the atmosphere from the polar to the tropical regions, where, from the operation of causes already pointed out, it is inclined to move from east to west. In this eastern movement the air encounters elevated lands, and, by its own inertia, flows up their sloping sides to a height which causes additional condensation to take place in the localities. The condensations produced in the last-named manner are, however, so considerable as to become the operating causes of the principal winds found within the tropical regions. The air that overflows from these tropical condensations then becomes new atmospheric currents, which, in their turns, encounter other sloping elevations of land, up which they are impelled, when fresh condensations become new causes of particular winds; and the winds produced in these various modes, both within and without the tropics, act and react on each other in all conceivable ways, varying with the season of the year, and the state of the dew-point, and producing an indefinite variety of changes.

The air, moving towards considerable elevations, produces different kinds of weather, according to its temperature and moisture; and an examination of it, at any time, may shew what weather will be produced by it in the locality; as, for instance, suppose the wind in St. George's Channel to change from a dry cloudless north or east to a south-west wind, any person, by ascertaining the dew-point and temperature of the latter wind, would be able to say, not only whether there would or would not be rain among the Welsh mountains, but also what would be the character of the rain, whether it would be slight or heavy. If the dew-point was near to the temperature, as soon as the wind climbed the mountains to a small extent it would be sufficiently cooled to condense much of the steam that it contained, when large cumuli would be formed about the mountains at a moderate height, and an ascending current created, towards which fresh air would rush, and a stronger wind would be the result, with heavy rain in the part. If, on the contrary, the dew-point was greatly below the temperature, the ascent of the air against the side of the mountain would not cool it sufficiently to condense any of the steam, and the atmosphere would remain clear. But if the dew-point was in an intermediate state clouds might be formed at some height, and either with slight rain or without any rain. Suppose, for instance, the temperature of the wind to be 60° and the dew-point 58°, in that case, when the wind had climbed 600 feet, cloud would begin to form. As the wind ascended higher condensation would become more energetic, and, however moderate the wind had been before, it would now become stronger. If the dew-point was 56° condensation would commence at 1,200 feet. At 54°, 52° and 50°, the heights at which condensation would commence, would be respectively 1,800, 2,400, and 3,000 feet. Should the dew-point be at so low a temperature as

48^0 no cloud would be formed by the ascent of air, as the height of the mountain is only 3,560 feet while the point of condensation would be 3,600 feet.

But cloud and rain may be formed in another way. Suppose the same air, with a dew-point of 58^0, to be moving very slowly on a summer's morning, and the sun to warm it near the surface of the sea or land successively, so as at last to raise it say 600 feet, and suppose the air so raised flowed against the mountains, it is evident that it would then have but little additional height to rise before condensation would commence. Or if there was a perfect calm, then the lower part might be warmed by the sun sufficiently to produce cumulous cloud, which might go on increasing until large masses of cloud were formed, and rain fell. From these facts it is evident that attention to the state of the dew-point may, in such a part, enable a person to tell in the morning whether it is likely that there will be rain during the day. The daily action of the sun, in warming and raising air and forming cloud, generally takes full effect before three o'clock in the afternoon, and if, by that time, rain do not fall from the cumuli which have been formed that morning rain from them need not be expected during the day; though it may be produced, through the air being forced up mountains, by a horizontal current.

Rain in England commonly comes from the south or west, because the winds which come from those quarters have generally a higher dew-point than other winds; but air which has rested on the north sea, until evaporation has produced a high dew-point, may be sufficiently saturated with steam to commence condensation on being either raised by the sun or forced up a hill.

In the summer and autumn, from the flat shores of Lancashire, when the weather is calm, a thick mist is frequently to be seen resting on the sea in the morning, which mist is generally raised by the action of the sun on the lowest stratum of air, until a well-defined stratus cloud is formed at some certain height. And, the dew-point being sufficiently high, by ten, eleven, or twelve o'clock, little protuberances begin to appear on the upper edge of this cloud, which soon swell into irregular cones, until either rain falls, or the cloud ascends to higher regions and dissolves, as the sun goes down. Occasionally, when this stratus has ascended a few hundred feet, and the protuberances are forming on the upper edge, the misty lower part of the atmosphere appears to separate into vertical films, with transparent spaces intervening, the whole presenting a view to the spectator of an immense hall or theatrical stage, hung with flags of film, some of them slightly tinged with prismatic colours. There is, at the same time, that peculiar tremulous motion which suggests the idea that warm air is ascending. From the whole of the appearances it may be presumed that they are results of the ascent of the warmed and, therefore, transparent air through the mist, in separate vertical columns or streams, as they proceed to the upper part of the cloud, there to be condensed and form the cauliflower-like tops of the cumuli.

Among mountains these cumuli sometimes swell and rise to a great height, and take a cylindrical form, with hemispherical tops, when heavy rains almost invariably fall. From the high grounds near Ramsey, in the Isle of Man, clouds of this description may frequently be seen, at the same time, over Down, Wigtonshire and Cumberland; and, from the heights of the clouds, and their approximation to the cylindrical shape, the observer may form an opinion respecting the quantities of rain falling in the parts. The clouds that accompany thunder storms, with sudden and heavy rains, are lofty cumuli, with hard outlines, the tops sometimes changing their shapes with considerable rapidity, as the steam varies its direction in the ascent.

INFLUENCE OF FORESTS ON CLIMATE.

Writers have frequently attributed to the presence of forests, or to their absence, the prevalence of a moist and cold or of a warm and dry climate. MALTE BRUN, as is usual with him, adopting the facts and opinions he finds in books, says—"In the Cape de Verde islands, it is the burning of the forests which has dried up the springs, and rendered the atmosphere sultry; Persia, Italy, Greece, and many other countries, have thus been deprived of their delightful temperature. The cutting down of the forests which once covered the Pyrenees has rendered the air very unwholesome in the valley of Azun, because the absence of that barrier now permits a free passage to the southern winds. Similar complaints are made in Castile and Arragon."—*See Malte Brun, vol.* 1, *page* 408. The idea that giving a free passage to winds makes the air very unwholesome seems strange, but we may suppose that the fact given is substantially correct, namely, that the place, from the operation of some cause, has become less wholesome since the trees were cut down. The almost universal opinion, founded on experience, seems to be that the removal of trees, and the leaving of the land exposed to the full influence of the sun's rays, make the climate drier and warmer. In parts of the United States of America experience is said to have shewn that cutting down the forests, and exposing the earth to the sun, renders the place drier and more salubrious, as the wood fever disappears.

But whatever may be thought of the healthy or unhealthy effect of clearing forests, there appears to be no doubt entertained that greater dryness is a consequence of such a proceeding; as, according

to numerous accounts, the earth then ceases to be equally moist, and the springs to furnish an equal quantity of water. But in what way does a forest furnish an additional supply of moisture to the earth, and of water to the springs? If trees produce these effects they must, in some way, cause more water to come to the part: and the question is—how is this effected? It has been said that they absorb moisture from the atmosphere, but that would tend to make the air dry instead of damp, and there is a contradiction in supposing that trees, at the same time, make the atmosphere damp by their evaporation and dry by their absorption. The fact, however, seems to be established from experience, in different ages and in various countries, that the presence of forests really made the climate comparatively wet, and their removal made it dry; but, in assigning a cause for these facts, we meet with the most crude and contradictory notions. This has, doubtless, arisen from the imperfect knowledge which has existed of the causes that determined the distribution of the supply of water, received from the atmosphere, to the various parts of the surface of the earth. That the chemical and physiological processes which are going on in trees do not bring a supply of water to the part in which they grow must be evident. Trees do not, by chemically uniting oxygen with hydrogen, form water. And it is not conceivable that they can take steam from the atmosphere by absorption, convert it into water, and convey that water through their roots to the earth, and thus furnish a supply of water which shall appear in the moistened soil and flowing springs; for if they did this they would make the atmosphere dry, and it is known that they make it moist. But if water cannot thus be furnished to the earth by trees, and if they yet do cause the climate to be more moist and springs to flow more abundantly, as is generally declared, it can be only by causing more rain to fall, and this we propose to shew is effected by a mechanical and not a chemical operation.

In the *Quarterly Journal of Science*, for 1829, page 93, there is a brief review of a translation of a work from the French of M. A. Moreau de Jonnes, which obtained a prize from the Philosophical Society of Brussels. In chapter the first of this work the author maintains that woods lower temperature, "on account of their dark colour," and because "they keep the soil damp." The reviewer thinks that the experiments cited by the author are so detached as to leave room for considerable objection. But both author and reviewer agree that the clearing away of woods makes the temperature of countries warmer.

In chapter two the author attempts to shew that woods, in flat countries, do not perceptibly increase the quantity of rain, but that on mountains they have an influence in producing that effect. And he maintains that the progressive diminution of rain in the south of Europe, which is stated to have taken place, is to be ascribed to the destruction of the mountain woods. But the way in which the woods are supposed to have produced the rain is not pointed out. In chapter four it is asserted that countries, especially mountainous countries, which are covered with woods, also abound more in waters

than others; but no reason is assigned, either by author or reviewer, why this should be!

It has already been shewn that one great cause which determined the quantity of rain in each country, was the existence or non-existence of elevated land. And elevated land produces condensation of atmospheric steam, and more or less copious rain, by causing the aeriform fluids constituting the atmosphere to ascend sufficiently high to commence the process of condensation of steam. Now if elevated land, by forcing the air to rise in the atmospheric space, causes condensation, it is evident that any other cause which shall, in like manner, force the air to rise in any particular locality, may produce a similar result. And if it can be shewn that forests have this effect, it will at once account for the fact so long observed, that the existence of forests renders the climate wet, and their removal makes it comparatively dry.

Any person looking from a mountain, on a cloudy storm raging in a valley below, may observe that the lower part of the storm moves with less velocity than the upper part, producing an irregular rolling or tumbling motion of the clouds, that evidently arises from the resistance which that part of the wind encounters that presses on the surface of the earth. The friction and obstructions on each particular part of the surface impede the progress of the lowest part of the air, and that other portion, which immediately follows, climbs over the lowest stratum of air, but in so doing it is itself impeded by the obstacle it has to encounter in the lower and retarded air. A third portion of air then climbs over the second, and in so doing is itself retarded; and in this way successive strata of air follow and climb over other strata that present obstacles to their progress, and thus form overlapping and rising currents, moving with increasing velocities as they proceed at a greater distance from the obstructions on the surface of the earth. And in proportion to the general force of the wind will be the comparative retardation of the lower, and the overlapping, climbing and ascent of the upper strata. If the air so proceeding is free from cloud, but sufficiently charged with steam, when it reaches a certain height, a part of that steam will be condensed through a reduction of temperature, and cloud will be formed, and the steam being sufficiently abundant rain will fall. This process must take place, to a greater or smaller extent, during every storm, even when the surface of the earth is bare, and consequently presents comparatively little resistance to the wind. But when such a storm encounters a forest the resistance that it meets with is materially augmented, and the retardation of the lower strata is greater, the overlapping and ascent of the currents are increased, more abundant condensation takes place, and more rain falls, making the place wetter than it would be if the forest were absent, and the bare ground alone left to retard the progress of the lower portion of the wind.

That the additional resistance presented to the wind by a forest is sufficiently great to produce considerable effects on the movements of the atmosphere is apparent. The force exerted in bending the

trees of a forest during a storm is very great; and nearly an equal force to that which is exhibited in bending the trees must be exerted by the air which presses against the trees in resisting the progress of that portion of the atmosphere which immediately follows; and that following portion will be retarded, in its lower part, by a force nearly equal to that by which the trees are pressed by the wind. But, as the resistance is from below alone, and the wind can proceed upwards, it takes an upward direction, until the lower strata of the air in contact with the trees, or near to them, by their successively diminished velocity, present an inclined plane of resistance to the air that follows, which forces it to ascend; the lowest stratum being the most retarded, and the diminishing retardation being communicated successively to the higher strata, and reaching to an elevation, proportioned to the force of the wind and the height of the trees. Thus we see that a forest, by presenting resistance to wind, to a certain extent forces that wind to rise, as, in other instances, it is forced to rise by the sloping sides of mountains, and both causes are capable of producing condensation of steam and rain.

What is called a forest has the trees generally close together, and of nearly uniform height, and these peculiarities will cause a less resistance to be presented to the wind, especially in a flat country, than would be experienced if the trees were farther apart, and of unequal height. A wind passes over a very thick forest almost without penetrating it, but when the trees are so far asunder as to admit the wind to reach the surface of the earth, in its passage from tree to tree, a separate resistance is presented by each tree, and the progress of the lower stratum of air is more effectually retarded. Should the trees be on the sloping sides of a mountain, which faces the quarter from whence the moist winds come, the effect will evidently be greater than if on a plain.

Presuming the view here taken to be correct, it will follow that, in a climate which is thought to be too wet, it will be advisable to avoid the planting of trees in such way as may materially retard the progress of winds. The western part of Scotland is considered by many persons to have a superabundance of rain. Such persons should recommend that, as far as respects climate, the hills of Scotland should be allowed to remain bare of trees. For certainly, if there is any truth in what is here advanced, the planting of the millions of trees in that country, as is stated in the newspapers to have been done from time to time, must have the effect of rendering that country somewhat wetter than it is at present. Ireland has been supposed to be too wet for certain important agricultural purposes, her clouded skies and frequent showers not allowing the sun to ripen sufficiently her crops of grain. If this be considered an evil, to plant the southern and western sides of her hills and mountains with trees would increase that evil, seeing that those trees would produce more clouds and rain than at present prevail in the country. In Castile and Arragon there is a deficiency of rain, hence the desirability of having, in those countries, trees planted on every suitable elevated ridge. Persia suffers greatly

from a want of water, and it is possible that a judicious and extensive system of planting trees in that dry country might cause the heavens to discharge more copious showers on its parched land than they do at present. The Cape de Verde islands are, during a considerable part of the year, within the influence of the north-east trade wind, or of the harmattan, which blows from the dry desert of Africa; but they have their comparatively moist season, and it is possible that reproducing those forests which have been burnt down might bring those showers that would again replenish the springs which it is said have been dried up. Were the Pyrenees once more covered with forests the south wind, which is supposed to be now unwholesome, might be forced upwards, and become an ascending current showering down rain, instead of passing, as it appears it now does, unobstructed through the valley of Azun.

As it is by retarding the progress of the lower portion of a wind that trees tend to produce rain, it follows that any thing else that, in like manner, retards wind, will have the same tendency. The windmills of Holland will have some effect of that kind, however small it may be. A large fleet of vessels leaving the docks of Liverpool, and spreading their sails over the Mersey, appears sometimes to almost stop the gentle south-wind that is blowing over the river; and, at other times, to bring on a slight shower of rain. And supposing the atmosphere so fully saturated with steam as to be in a condition to condense a portion of it on a trifling elevation of the air taking place, the impediment presented to the wind by the sails of a hundred ships might force it upwards, and cause condensation to commence, and produce rain. A great battle at sea, is said, at times, to cause rain to fall; and it evidently may do so, if the gases generated by the firing of gunpowder should force the moist atmosphere to ascend to a sufficient height. It is to be recollected that the air may be in such a state of saturation that a small ascent of any part of it must by cooling it produce a cloud, and rain may be the result: and it is only when the atmosphere approximates to such a state that rain can be produced from such comparatively trivial causes.

In inquiring into the influence of forests on temperature some obscurity has occasionally appeared on account of the absence of a proper distinction between the warmth arising from the solar rays heating the surface of the ground, and that warmth which is derived from the condensation of atmospheric steam. On clearing a country of trees fewer clouds are formed, the surface of the land is consequently more exposed to the direct action of the sun's rays, and the temperature of the surface is raised. In the drier season of the year there may then be little or no rain, and therefore little evaporation to cool the surface of the land, which may consequently become hotter, and vegetables may ripen which would not come to maturity when clouds obstructed the solar rays, and copious showers moistened the ground. But the same removal of forests which thus made the summers hotter, might, and in this part of the world would, prevent condensation of steam from taking place in the winter to

the same amount as before, and consequently would prevent the winter from being warmed by heat from condensed steam. The winters would, therefore, become colder, though the summers would be warmer, and it might be that the increase of the temperature of the one would be equal to the decrease of the temperature of the other, and the mean or average remain the same. Were England denuded of trees on the elevated lands having a south-western aspect, it might be that the heat of summer would, in certain parts, ripen the vine, as it is now ripened on the banks of the Rhine: but the winter climate of England also might approximate towards that of the Rhenish provinces. England now has a climate of the nature of the warm and moist, the warmth being, in a great degree, furnished by rain, particularly in the beginning of winter, and this kind of climate is, to a certain extent, produced by the trees which are so abundant in the country. And in the summer it is cool for the latitude because clouds screen the surface of the ground from the sun, and the same trees tend to produce these clouds. The plains of Prussia and Russia, which are in the same latitudes as England, have a climate of the nature of the hot and dry in the summer, the sky being then generally cloudless; but in the winter, with these cloudless skies, the cold is intense compared with that which is found in England. Now were forests so planted in those countries as to produce more of clouds in summer and of rain in winter the climate would, to some extent, approximate to that of England. The mean temperature of the year might, in these countries, continue the same as it is at present, but the climate might be said to be either colder or warmer according as attention was directed to the alteration which had taken place in the winter, or in the summer.

ATTRACTION OF CLOUDS BY MOUNTAINS.

It is common to find, in the works of intelligent writers, allusions to the *attraction* of clouds by mountains. Such attraction seems to be assumed as a fact, the existence of which there was no room to doubt; and the movements of clouds towards mountains, so generally observed, has been universally attributed to this attraction. MALTE BRUN speaks of vapours and clouds being *attracted* by mountains. Thus he says—"Mountains act upon climates in two ways, they *attract* the vapours suspended in the air—these vapours, by their condensation, produce clouds and fogs, which conceal the summits from our view."—*Vol.* 1, *page* 403. And Captain FITZROY says—"The islands of the dangerous archipelago have no hill or height

of any kind, about which clouds *attracted* by them, taken together, can gather and discharge a portion of the contents."—*Page* 507. And this is the general language of writers on the subject.

It requires very little reflection to perceive that the movements of clouds towards mountains are not likely to be an effect of the attraction exerted by the mass of the mountain on the matter contained in the cloud. The force of attraction of the mountain, as compared with that of the earth, is as the respective weights of the two masses: the force of attraction of the largest mountain, as compared with that of the earth, is, therefore, so small as to be scarcely appreciable. But whatever that force may be, it can only be exerted in collecting round the mountain a cone of air of a little more density than that which exists in the atmospheric space, at the same elevation, at a distance from the mountain, just as the earth, by its attraction, collects the whole atmosphere around itself. Such a cone of air about a mountain may be conceived, but cannot be traced. When a cloud is floating in the air towards a mountain, as is often seen, its specific gravity cannot be materially different to that of the air in which it is suspended, for if it were it would fall rapidly to the earth; and yet it could be in consequence of its *superior* specific gravity alone that it could, in any degree, be attracted by the mountain. For if the cloud were of the same specific gravity as the adjoining air it would, as far as attraction affected it, form a part of the cone, and would, consequently, be stationary, as, when once the supposed cone is formed, no cause exists for the movement of any part of it towards the mountain; it is then only the superior specific gravity of the cloud that can be acted upon by the attraction of the mountain. But if the cloud had any appreciable superior specific gravity to the air in its vicinity, it would fall not towards the mountain but towards the body having the infinitely stronger attractive force, which is the earth. And as those clouds which flow towards mountains do not appear palpably to fall towards the earth, and sometimes really rise from it, they cannot have sufficient gravity to enable the mountain to attract them. The notion, therefore, that mountains attract those clouds which are frequently seen sailing towards them must be fallacious, and there must be some other cause for the phenomena observed, as there is no doubt about the fact that clouds do frequently move towards mountains.

Again, if the attraction of the mountain drew the clouds towards it, they would, when they had reached it, remain attached to it. But it is common to see clouds sailing towards mountains slowly and majestically, then ascend them to some particular height, roll over their sides, and flow away with about the same slow movement as that by which they approached. Now if it were attraction that drew such clouds, the same attraction would hold them, yet they are not held, and, therefore, we must infer that such attraction does not exist. Sometimes clouds flow towards mountains from different and even opposite quarters, and this is frequently considered proof of the existence of sufficient attractive force in the mountain to draw the cloud. MALTE BRUN says—"The South Sea islands, notwith-

standing their small circumference, in this manner, as in a sea breeze during the day time, attract the general east wind, which is thus made to embrace them, as it were, on every side, and to blow from all points of the compass towards the central parts of the island."—*Vol.* 1, *page* 385. What has been already advanced will be sufficient to account for such phenomena as those just described, without being obliged to suppose that an attractive force in the mountain has been the cause in operation. But it may be here repeated, that when air charged with steam is made to ascend a mountain sufficiently to produce any condensation of that steam, an ascending aerial current is formed, and into this ascending current air may flow from all parts around the mountain. If the condensation be considerable the influx of the surrounding air will be also considerable, and winds will blow strongly from all points towards the mountain; and should any clouds be suspended at a suitable height in the neighbourhood at the time, they would flow with the wind towards the mountains, about which a mass of cloud would be collected. It may, perhaps, be asked what becomes of these clouds? And the reply to such a question is, that they are condensed in their ascent, and converted into rain, as shewn in an extract from Cook, in *page* 36. The general east wind which prevails in the Pacific was blowing at the period referred to, and that wind, when it encountered the mountains, was impelled up their sides to a sufficient height to produce condensation of a portion of the steam which it contained; hence an ascending aerial current in the part, and the fall of rain. But as the clouds, or such parts of them as were not condensed into rain, were carried forward by the general trade wind, and descended towards the level of the sea into a warmer atmospheric region, they were dissolved into steam, and, by becoming transparent, disappeared.

It is evident that phenomena of this kind must be modified by different causes, such as the height and shape of the mountain, the strength of the general wind, the quantity of steam in the air, and, perhaps, by atmospheric currents flowing at different heights charged with various portions of steam. When a cloud is formed, and that cloud is carried away by a general current into a lower and warmer region, the particles of water which constitute the cloud will evaporate and become steam, and that portion of the atmosphere in which the evaporation has taken place, will be, temporarily, more fully charged with steam than other portions, at the same height. In this way different local planes or levels in the atmosphere may, for a time, be charged with different proportions of steam, one plane having a charge nearer to the maximum quantity than another. Suppose such an atmosphere to move slowly towards a mountain, and the whole to climb its ascent from the mechanical force of the wind, it is clear that the different planes in the atmosphere would present evidences of condensation having taken place in the formation of cloud according to the abundance of the steam in each part. In the sixth volume of Cook's Voyages the following account is given:—"A volcano stands not far from the west coast of North America, and in the latitude of 54°—48′. The volcano is at the top of the cone,

and we seldom saw this, or indeed any other of these mountains, wholly clear of clouds. At times both base and summit would be clear, when a narrow cloud, sometimes two or three, one above another, would embrace the middle like a girdle, which, with the column of smoke rising perpendicular to a great height, out of its top, and spreading before the wind into a tail of vast length, made a very picturesque appearance."—*Page* 381. Phenomena, similar in their general character, may be observed in many mountain countries. They may be seen in North Wales against the south and west sides of Snowdon. From Beaumaris, when say a south-westerly wind is blowing, there will, at times, be no cloud brought from a distance by the wind. But when this wind blows against the sloping side of Penmanmaur, and is driven up it, at a certain height cloud is formed, which, as it proceeds upwards, becomes more dense. Rain then falls from the dense part of the cloud, whilst portions of it are driven round the sides of the mountain over the Irish Sea, where they frequently dissolve by evaporation. The top of the mountain all this time may be clear, but that depends on the hygrometrical state of the air. The process and appearances described may, however, continue for hours without material alteration, cloud being regularly formed from the previously transparent air, and a part condensed into rain, whilst another part floats away and is dissolved. When a person is on the top of a mountain, whilst the circumstances just described are taking place below, the cloud may be looked down upon, and generally its upper part has an irregular white and fleecy appearance. These circumstances do not favour the notion that mountains attract clouds.

The eastern side of the Andes has already been noticed as a region of condensation, but the clouds that are formed in that region do not approach the Andes as if attracted by their large masses. The mountains are lofty, and, in many parts, rise abruptly from a low level, and if they exerted an attractive power on clouds would draw the clouds against their sides, where they would adhere and take the shapes of the sides of the mountains. But such is not the state in which clouds are found in this part of the world, as will appear from the following description which relates to a part on the eastern side of the Andes, at some distance from the tropical region of great condensation.—"March 23. The descent on the eastern side of the Cordillera is much shorter or steeper than on the Pacific side, in other words the mountains rise more abruptly from the plains than from the Alpine country of Chili. A level and brilliantly white sea of clouds was beneath our feet, and thus shut out the view of the equally level Pampas. We soon entered the band of clouds, and did not emerge from it that day." Again—"March 24. I enjoyed a far extended view over the Pampas. At the first glance there was a strong resemblance of a distant view of the ocean, but in the northern parts many irregularities in the surface were soon distinguished. In the middle of the day we descended the valley, and heard that the silvery clouds, which we had admired from the bright region above, had poured down torrents of rain."—

Darwin, page 401. Here the air on the plains, stopped by the mountains, attained a sufficient height to produce condensation and form cloud, and this cloud, it appears, extended over the flat Pampas and was apparently equally level with them; and within this extended flat cloud torrents of rain had poured down. These facts are in accordance with the theory of condensation from cooling by ascent, but not reconcilable with the belief that mountains attract clouds. These mountains are some of the largest in the world, and they present their steep sides abruptly to the plains where clouds are formed, but there is no clustering of the clouds against their sides, like iron filings to a magnet, as there would be if this theory of attraction were true.

ON STORMS.

Storms, as they often materially affect the well-being of man, have in all times arrested attention, and have frequently stimulated inquiry into the causes which produce them, yet no satisfactory account has ever been given of those causes. Recently considerable industry has been exhibited, particularly in the United States of America, in collecting facts relating to the peculiar action of storms. Mr. REDFIELD has attempted to shew that they are whirlwinds, with a progressive motion; and Colonel REID, in his book on storms, has advocated the same theory. But while the facts adduced by these gentlemen are admitted to be substantially correct, the inferences from them have been disputed by Mr. ESPY, who maintains that all storms are strong winds converging to a central part or line, where an ascending current exists; and he maintains that such converging winds, having a progressive motion, will produce appearances somewhat similar to those observed by REDFIELD and REID, and which, he says, they erroneously attribute to whirlwinds.

As storms commonly extend over a large area, and the motion of the air during their continuance is rapid and, to a considerable extent, irregular, it has been found difficult to collect facts sufficiently minute and accurate respecting the strength and direction of the wind in the various parts where the storm has raged. And a progressive whirlwind might certainly present phenomena so similar to progressive converging winds, as to render it difficult to determine whether the particular facts observed are more in accordance with the one theory or the other.

Mr. REDFIELD does not profess to give any theory to account for storms, but confines himself to endeavouring to prove that they take the form of whirlwinds, whilst Mr. ESPY maintains that storms are converging winds, and he also attempts to shew what the causes are which produce these winds; and thus he professes to explain the causes as well as the peculiar action of storms.

We shall attempt to shew presently that all storms are not produced in the way described by Mr. ESPY; but supposing, for the present, that he is, to a certain extent, right in his theory, may it not follow that when some storm has been produced in the way he states, it may afterwards take the form of a whirlwind?

Motion in air is so rapidly communicated to adjoining air, and our means of observing the particular motions of the various parts of a large mass of air are so imperfect, as to make it difficult to detect and follow irregular movements that take place in the atmosphere, whatever they may be. But from what is known of the state of our atmosphere we may suppose that, on condensation producing an ascending current, if the supply of steam was equal on all sides, a nearly vertical ascent would be the result, and equal quantities of air would flow horizontally from all sides to supply the vacuum thus produced. But if one side furnished more steam than another there would be a greater vacuum on that side than on the other, and, consequently, a more rapid rush of air from adjoining parts of that side into the vortex, which might possibly give it a spinning motion, in addition to its ascending motion. This being admitted, it would follow that if an ascending current, with a progressive motion, should traverse a part of the atmosphere where the dew-point is higher on one side than on the other, the ascending current might first take a spiral form, and ultimately become a whirlwind.

The localities where whirlwinds are said to be the most frequent and violent are the West India Islands in the northern, and the Islands of France and Bourbon in the southern, hemisphere. The former are within the latitudes of say 10° and 23° north, and have a trade wind blowing on them from the east, extending in breadth say about thirteen degrees. This trade wind, by the time that it reaches the islands, is pretty fully charged with steam, but it is to be presumed more fully on its southern than on its northern side. On the southern side, in the latitude of say 10°, the dew-point shall be say 73°, and on the northern side it shall be 70° or 65°, or some other lower point. Now, suppose an ascending current to be formed in the middle of this trade wind, about Antigua, and then more steam would come from the east on the southern than on the northern side, and this superior quantity, in its ascent would, on condensation taking place, give out more heat on the southern than was at the same time given out on the northern side, and cause a more rapid ascending current on the former than on the latter side. Suppose further, the ascending current to spread and extend to the latitude of 10° south, and an equal distance north, and then the trade wind would supply this area or ring with a quantity of steam expressed

by a dew-point of suppose 73°, or a sixtieth of the then existing whole atmosphere, while on the northern side the same wind might supply a quantity of steam expressed by a dew-point of suppose not more than 52°, or a one hundred and twentieth part of the atmosphere, or the difference in the dew-points might be less than this. But as the rushing in of the air below to supply the ascending current, in any part of the ring, would be proportioned to the amount of condensation in that part, the rush of air from the east on the southern side would be greater than that on the northern side, and this being continued, might cause the ring to revolve horizontally, at the same time that the air was ascending. Thus the wind, which, under these circumstances, would be found near the surface of the globe in the neighbourhood of the vortex, would be determined by the joint forces of the ascending and revolving currents, the ascending tending to produce converging winds and the revôlving whirlwinds, while the whole had a progressive motion produced by the general flow of the trade wind. If the storms of the West Indies are created in this way, they would be likely to take their rise in the part where the trade wind first encounters disturbing causes sufficient to produce an adequate ascending current. At the commencement of the storm converging winds would probaby blow towards the area of ascent, but as that area increased in size, the superior supply of steam in the southern part would cause that part to move forward with greater velocity than the northern part. And the greater quantity of steam and, consequently, stronger wind that would come from the south and east might not only cause the outer part of the ascending current to spin round, but might also press the whole mass of the storm northward. And thus the storm taking more or less of the character of the whirlwind in this part would, in its progress, be bent from the western direction towards the north, and would cross the northern part of the West India Islands, and the adjoining portion of the continent of America, and be turned round into the Atlantic Ocean. That the storms of the West Indies at times take about this course is very probable—they are said to blow from east in the southern part and from the west in the northern part. When the storm was thus pressed northward and had reached a certain latitude, the southern part of it alone would be acted upon by the trade wind, which would evidently dispose it to become more decidedly a whirlwind.

Colonel Reid shews that storms take place in the Indian Ocean, about the islands of France and Bourbon, in a way similar to those which occur in the West Indies. And these islands are, with reference to atmospheric currents, somewhat similarly circumstanced to the West Indies. A south-east wind generally blows from Australia, say between 20° and 40° of south latitude, towards the Cape of Good Hope, passing south of but not far from the isles of France and Bourbon, which are in 20° south latitude. And when the south-west monsoon blows strongly it is found to proceed from Madagascar towards the islands of Sumatra and Java, passing not far from the two first named isles. It is well known that the dew-

point is high about these isles, and the atmosphere is often calm for a considerable period. But suppose an ascending current to be formed near them, with an area or ring large enough to have a part in the south-east trade wind, or in the south-west monsoon, while the opposite part was either in a calm or in the opposite wind, and we should have similar causes in operation to those which we have just traced in the West Indies, and the outer part of the ascending current might be made to spin round—or a whirlwind might be the result.

These whirlwinds are said to prevail more particularly in the localities named, but if the foregoing reasoning is correct, it is evident that whirlwinds may be formed wherever the causes which it is here supposed produce them exist. An ascending current, acted upon by an unequal supply of steam in different portions of the outer part, may take an eddying form, as all fluids seem liable to do when in motion; and wherever steam is most abundant, and at the same time unequally distributed, there the effects will be the greatest and the whirlwind the most powerful. In the British Islands it is probable that a south-west wind, fully charged with steam, may often be found blowing in the neighbourhood of a north-east wind, and supposing condensation to commence in a part of the south-west current which is near to the north-east wind, and a ring of ascending air to be created which shall enlarge until it spreads into the north-east current, then the south-west wind would be carrying the ring in one direction while the north-east would be carrying it in the opposite direction. But as the supply of steam came principally from the south side, the form of the partial vacuum created would be consequent on the ascent of the superior quantity of air from that side, and the general direction of the storm might be altered or bent from its first course.

It appears then that the whirlwinds of REDFIELD and REID may exist, and may be products of the ascending currents and converging winds of ESPY—condensation of steam being the primary cause of both. But here a new question arises! Are all storms, as Mr. ESPY maintains, produced by ascending currents alone? Storms are but strong winds, and it is certainly but reasonable to suppose that the same causes which produce ordinary winds produce strong ones, and create storms. Condensation of steam being the great general cause of all the considerable movements of the atmosphere, it appears to follow, and must indeed be presumed to be true, until we have evidence to the contrary, that the most violent of these movements, storms, are results of condensation. But Mr. ESPY contends, not only that storms are results of condensation, but also that they are horizontal converging winds rushing to a centre or central part, where an ascending current exists, and that all storms are thus produced, and are converging winds. Now in so moveable a body as the atmosphere, where one part so readily acts on another, it may be found that violent action of one kind may produce violent action of another kind. And if facts frequently observed in storms do not agree with the theory advanced by Mr. ESPY, it may reasonably be

suspected that some second cause is in operation: and we may endeavour to discover the particular action of that second cause.

When copious condensation commences in any particular part of the atmosphere, an ascending current, as has been shewn, is formed, and a comparative vacuum created. The expansion of the air in this vacuum cools it, until more steam is condensed, more heat liberated, and the air again warmed and raised. The adjoining air, not having the same resistance as before in the part where the vacuum is formed, expands into it, and in so expanding is also cooled: and the greater the vacuum the greater will be the expansion, and the consequent cooling. It follows from this, on Mr. ESPY's theory, that in all storms, and especially in all violent ones, the barometer should fall, the wind become cold, and the thermometer should sink. For as, in the part, the barometer fell from the existence of a comparative vacuum near the earth, so the thermometer should sink from the expansion of the air in that vacuum. Now if, during the violence of a storm, the thermometer, instead of falling should remain stationary, it might be presumed that such stationary state indicated that the storm was not the expanding of air to fill a vacuum, but that it was produced by some other cause.

When air is suddenly heated and a considerable vacuum produced, and a rapid ascending current formed, a large mass of the air must be discharged in the upper regions. And this mass may be thrown on adjoining parts so suddenly as to penetrate those parts and descend again to the earth. This perhaps could not take place to a great extent if air alone was in motion, but the ascending current produces drops of water, and as soon as the force which carried the current upwards was expended, the force of gravity of the drops of water would cause them to fall. And in falling they might bring with them a large portion of the air that had been discharged above by the ascending current. Now such air having been previously heated by condensation, when it reached the surface of the earth might be warm, and a thermometer placed in it would be stationary, or might even rise.

The great storm which swept over the British Islands on the night of the sixth and the morning of the seventh of January, 1839, moved in about the direction of S.W. or W.S.W. passing over Ireland and the middle of Great Britain; and when that storm was at its greatest height, say from two to six o'clock of the morning of the seventh, the atmosphere was warm to the feelings. In the accounts which appeared in the newspapers the state of the thermometer was not often given, yet notwithstanding that the wind blew so fiercely, no complaints appear to have been made of cold by those who were exposed to the storm. At Rochdale, at five o'clock on the morning of the seventh, the barometer is stated to have been at $27\frac{8}{10}$ inches, and it is to be presumed that it was about equally low in other parts where the storm raged, though, it being night, the fact has not been noted. Now, if the wind which blew at this time consisted of air rushing by expansion into a vacuum, that air would be cooled by the expansion about ten degrees of Fahrenheit. But no cooling is

noticed, and none appears to have taken place; we may, therefore, infer that the wind which blew so furiously in this storm was not air expanding into a vacuum.

Another striking fact appeared at Manchester during this storm. From one until five o'clock, and probably later, in the morning of the seventh, while the wind was blowing furiously, the sky was quite clear—not a cloud appearing. The storm did not here begin until after midnight, and it may be said that the heavens were free from clouds during the first four or five hours of the storm, and if that storm was merely the rushing of air to fill a vacuum caused by an ascending current, which ascending current produced clouds and rain in the higher regions of the atmosphere, why had we neither clouds nor rain at Manchester during the time? On Mr. ESPY's hypothesis, with such a storm as that of the 7th January, we ought to have had a cold wind made colder to the feelings by its great velocity, and also at the commencement, as well as during the progress of the storm, dark clouds and heavy rain, but we experienced none of these! Nor does copious rain appear to have fallen in any part of Ireland or of England, over which the storm swept with the greatest violence,

That condensation of an abundance of steam and a consequent vacuum, and ascending current, perhaps over the Atlantic Ocean, may have originated this storm, is not only possible but probable: but that the storm, as it swept over these islands, was not the rushing of air to fill a vacuum is sufficiently clear. It had neither the coldness, the cloudiness, nor the rain that would have been consequent on such a process. But if we suppose the ascending current to have existed, say over the Atlantic, and a large quantity of air, mixed with rain, to have been there carried up sufficiently high to have penetrated a south-west current in the higher regions of the atmosphere, which was moving with great velocity; and if we further suppose the ascended mixture of air and rain, afterwards to descend, and in its descent from the height to which it had been carried, to have brought down this south-west current, moving with great velocity, to the surface of the earth, all the principal facts which appeared in this storm will seem to be natural effects. The south-west current, when thus brought down and subjected to additional atmospheric pressure near the surface of the earth, might be warm, and having come from such a height would have but little steam in it, and, therefore, would not be disposed to form rain, or even to be cloudy. And if we suppose the whole of the atmosphere in the locality, up to a considerable height, to be made up of the descended wind, the superior warmth and consequent elasticity of this thick stratum of air would reduce its gravity, and cause the mercury in the barometer on which it rested to sink. In this way we should reconcile the facts of having, at the same time, a warm air and a low barometer, which, on Mr. ESPY's theory, seem to be incompatible. That a south-west wind might be moving with a high velocity in the higher region of the atmosphere, at such a season of the year, in the locality, is probable, as such wind is known to exist, and frequently reaches the surface of the earth as a warm wind, though in a less

abrupt manner than it seems to have done at the time of this storm. And sufficient reasons have been advanced to shew that extensive condensation may suddenly bring an upper current down to the surface of the earth.

On the evening of Friday, the 25th March, 1840, a violent storm from the south-west, west, and north-west, visited Greenock, Dumfries, Glasgow and parts adjacent, which did great damage. The *Dumfries Courier* says—"On the coast the storm was truly terrific, and, as usual, serious fears are entertained for the fate of many a vessel at sea. The moon, however, shone so brightly that the night was nearly as clear as the day; of itself a great blessing, during a night tempestuous beyond description." This storm was probably also a descended current, which had been moving at a high velocity in the upper regions, and which had been brought down by causes similar to those already described.

Numerous accounts, in the works of travellers both by sea and land, may be found of storms, which indicate that they were the outpourings of an ascended current, bringing air from the upper regions, rather than the expansion of lower air into a vacuum. Captain Fitzroy, speaking of a "pampero," near the mouth of the River Plate, states that it took place in the middle of the rainy season, the time when the steam of the tropics is passing southward towards cooler regions, corresponding with July in the West Indies, and he writes thus:—"On the 30th January, 1829, the *Beagle* was standing in from sea towards the harbour of Maldonado. Before mid-day the breeze was fresh from the north-north-west, but after noon it became moderate, and there was a gloominess and a close sultry feeling, which seemed to presage thunder and rain. During three preceding nights banks of clouds had been noticed near the south-west horizon, over which there was a frequent reflection of very distant lightning. The barometer had been falling since the 25th slowly but steadily, and on the 30th at noon it was at 29.4 inches and the thermometer at 78°. At about three o'clock the wind was light, and veering about from the north-west to north-east. There was a heavy bank of clouds in the south-west, and occasional lightning was visible even in daylight. There were gusts of heated wind. At four the breeze freshened up from north-north-west, and obliged us to take in all light sails. Soon after five it became so dark towards the *south-west,* and the lightning increased so much, that we shortened sail to the reefed topsail and foresail. Shortly before six the upper clouds in the *south-west* quarter assumed a singularly hard and rolled or tufted appearance, like great bales of black cotton, and *altered their forms so rapidly* that I ordered sail to be shortened, and the top sails to be furled, leaving set only a small new foresail. Gusts of hot wind came off the nearest land at intervals of about a minute. The wind changed quickly, and blew so heavily *from the south-west,* that the foresail split to ribbons, and the ship was thrown almost on her beam ends! The main topsail was instantly blown out of the men's hands, and the vessel was apparently capsizing—when top masts and jib-boom went close to the caps, and

she righted considerably. Two men were lost. The starboard boat was stove by the force of the wind, and the other was washed away, and so loud was the sound of the tempest that I did not hear the masts break though holding by the mizen rigging. Never before nor since have I witnessed such strength or I may say weight of wind; thunder, lightning, hail, and rain came with it, but they were hardly noticed in the presence of such a formidable accompaniment! After seven the clouds had almost all passed away; the wind settled into a steady *south-west* gale, with a clear sky."

In this account it is to be observed that the clouds from which the storm appeared to come were, when first observed, very heavy in the south-west, in which direction there would, therefore, have been great condensation of steam and much rain formed. The ascending current, which it is presumed produced the condensation, the clouds and the rain, was at last apparently poured out from the south-west towards Maldonado, and the rain in its descent probably forced the wind in the direction of that place. Immediately *before* the storm gusts from the north-north-west came off the nearest land at intervals of a minute, when "the wind changed *quickly*, and blew so heavily *from the south-west*, that the foresail split to ribbons, and the ship was thrown almost on her beam ends." Now are not all these facts such, or nearly such, as would be likely to occur if we suppose much rain to be formed and first carried to a certain height in the atmosphere from which it would descend by its own gravity, but projected by the expansion of air that was taking place at a particular elevation in an ascended current? It could not be the centre of an ascending current such as is described by Mr. Espy, which was passing from the south-west towards the north, as such a current would have been first strong from the north, then a calm would have been experienced in the centre under the vortex, and then would come the south-west wind flowing towards the vortex, which would be at first rather an ascending than a horizontal current, and the increase in the strength of the horizontal wind must have been gradual. The storm could not be one side of such an ascending current, seeing that such a change in the direction, and sudden burst of strength of the wind, is incompatible with what must then have taken place. And what conceivable cause could produce such *sudden* "strength or, I may say, weight of wind" as that described by Captain Fitzroy, except the one supposed—the descent of a heavy torrent of rain, expelled and projected by an expanding mass of air?

In the same book, vol. 1, it is stated that, when in the southern part of Tierra del Fuego, "at Port Waterfall, near Port St. Antonio, we noticed some extraordinary effects of the whirlwinds which so frequently occur in Tierra del Fuego. The crews of sealing vessels call them 'williwaws,' or hurricane squalls, and they are most violent. The south-west gales, which blow upon the coast with extreme fury, are pent up and impeded in passing over the high land, when, increasing in power, they rush violently over the edges of precipices, expand, as it were, and, descending perpendicularly, destroy every thing moveable. The surface of the water

when struck by one of these gusts is so agitated as to be covered with foam, which is taken up by them, and flies before their fury until dispersed in vapour. Ships at anchor under high lands are sometimes suddenly thrown over on their beam ends, and the next moment recover their equilibrium as if nothing had happened. In the Gabriel channel 'the williwaws,' bursting over the mountainous ridge which forms the south side of the channel, descend, and, striking against the base of the opposite shore, rush up the steep and carry all before them."

In this account the south-west wind is represented as being "pent up and impeded in passing over the land;" the barometer, however, would shew that there was no increase of density in the air when it was passing over the high land. The extreme fury of the south-west gale may, we presume, have arisen from the sudden expansion of the air in those high parts. But we are told that very heavy rains are also produced by these gales, and those rains descend to the surface of the earth. Now supposing this rain to fall from a great height near the precipice it must bring air with it, and, increasing in power as it descended nearly perpendicularly, it might become a storm and destroy every thing moveable. Such a mass of rain and air falling on and striking against water would agitate it, cover it with foam, and the air, in its elastic rebound, might carry away the foam, as winds carry the spray of the sea, until it was at last dispersed. Sudden and copious rain falling among mountains will have a tendency to bring down air over a certain space, and momentarily to compress it into a somewhat smaller space, as the valley, lake or bay into which the rain falls contracts in size below. And the part of the storm of wind and rain that reaches the earth may, under these circumstances, be driven down like the edge of a wedge, or the point of an inverted cone, in which is concentrated all the force exerted above, temporarily compressing the air and forcing up the barometer. It should also be recollected that the expanding air may, at certain heights, meet with descending rain, and the joint force of the two may act in all conceivable modes, particularly in the irregular spaces included between contiguous mountains. Horizontal currents of air alone evidently have not the power to produce the effects described in the extracts. For supposing a horizontal current to be of great force, and driven up one side of a mountain, when it reached the top, and passed over the precipice, it would meet with greater resistance from below than from above, and would, consequently, be more disposed to ascend than to descend. The force of gravity of some body more ponderous than air is necessary to produce such a vertical descent as takes place in these local storms called "williwaws," and that force seems obtainable from rain alone, as no other body is present to furnish it. The figure used in the description of "bursting over the mountainous ridge" can mean no more than that the "williwaw" was first observed coming from that part. Rain might have been descending from one current, and while in that state be caught and thrown over, or off from the ridge, by another ascending and expanding

current, and the projectile force with which the rain was thrown, and its own gravity, might carry it to the base of the opposite shore, where, intermingled with air, it would rush with a force proportioned to its velocity. These descending gusts of wind are almost always stated to be accompanied by rain, either in them, or near them, but the rain is generally spoken of as brought by the wind; it is, however, desirable that these phenomena should be observed with a supposition in the mind of the observer that the rain may be the cause of the wind rather than an effect of it, in order that it may be seen how all the facts will harmonize with such a supposition.

LAIRD and OLDFIELD, when in Africa, thus describe a storm on the Niger.—"There is something awfully grand and impressive in the appearance of the heavens before a tornado. A dark mass of clouds collects on the eastern horizon, accompanied by frequent loud but short noises, reminding one of the muttering and growling of some wild animal in a voice of thunder. This mass or bank of clouds gradually covers one half of the horizon, extending to it from the zenith; but generally before this a small and beautifully formed radiant arch, on the verge of the horizon, appears, and gradually increases. Long before it reaches the vessel the roaring whistle of the whirlwind is heard, producing nearly as much noise as the peals of thunder that seem to rend the very clouds apart from each other. The course of the squall is distinctly marked by the line of foam it throws up, and I have stood on the taffrail of a vessel, and felt the first rush of the wind while her head sails were becalmed. The sensation it produces afterwards is cheering and delightful. From breathing a close and murky atmosphere, loaded with unpleasant vapours that invariably precede the tornado, the mind becomes relieved, as it were, from a load; the air is fresh and clear, and every thing around is fresh and exhilirating."—*Vol.* 1, *page* 58.

Can such a storm as this arise merely from the expanding or rushing of air into a vacuum? Converging winds, moving towards a centre, cannot have in their front such an abrupt edge as this storm had; as these winds, when approaching their centres, will curve upwards. And the air which is farther from the centre, and which follows the first rush, will be, in a continuous stream, produced by successive expansions, and increasing in force up to some point; which stream, however, will, at a certain distance, become weaker, until it at last disappears at the outer extremity of the storm. But in this African storm the cloud was seen in the east, the roaring whistle of the wind was heard before it reached the vessel, and its locality and progressive course were distinctly marked by the line of foam which it threw up, and it came so abruptly that the writer stood on the taffrail of the vessel and felt the first rush of the wind, while her head sails were becalmed! These circumstances may be conceived to have resulted from the outpouring of an ascended current which had carried much rain into a high region of the atmosphere, where there was possibly a sudden expansion of air: or a rapid upper current might have

existed, a part of which may have been brought down by the descending rain, and which continued its rapid motion as described, until, at some distance, its force was expended by the resistance of the lower air: but the facts appear utterly irreconcilable with the supposition that the storm was the immediate effect of air rushing into a vacuum. We are told too that previously to the storm the atmosphere was close and murky, but afterwards it became clear, and every thing around was fresh and delightful. From this account the lower air before the storm was evidently fully charged with steam, but the air which constituted the storm, if it came from a height where much steam could not exist, must have been dry, and hence the delightful sensations spoken of.* Had we the dew-points immediately before and after the storm, it is to be presumed that they would show a great reduction in the quantity of steam in the atmosphere. Even the arch that appeared, when the storm was at a considerable distance, may be explained on the theory here suggested. The ascending current, in which we presume the storm originated, had its condensation commenced at some certain height, dependant on the hygrometrical state of the air, say at such an altitude as would enable a person at a moderate distance, looking at it in profile, to see the transparent space beneath the lowest level at which the cloud was formed. And as that level would be at about a uniform distance from the earth, it would take the curve of the earth, and the radiant or transparent space below would seem to have an arched top.

Descending gusts of wind have been often noticed and described in a general way. MALTE BRUN, when speaking of a hurricane, says—"It begins in various ways: sometimes we have a little black cloud appearing on the summit of a mountain; at the instant when it seems to settle on the peak, it rushes down the declivity, unrolls itself, dilates, and covers the whole horizon."—*Vol.* 1, *page* 387. It is not easy to conceive that this can be anything but the out-spreading of an ascended current, which had carried condensed steam to some certain height, and there poured it out, driving it, by the expansion of the air in the current, until it covered the horizon.

In the British Islands, in the storms of autumn and winter, it is common for gusts of wind, frequently with rain, to come suddenly, and as suddenly to cease. Now how can it be conceived that there can be such an abrupt change, as is exhibited in these sudden storms, in the force of a horizontal current? No adequate cause for such a change can be traced. But if we suppose a local formation of rain at a considerable height in the atmosphere, and a projection and descent of that rain at some angle determined by its own gravity, and the direction of any current of air which may have acted upon it, or through which it may have passed, all that takes place seems natural and probable. In the southern parts of the United States of America it is said that storms are sometimes experienced which seem

* Dr. CLARKE describes a storm which he encountered in the Black Sea. Chapter 25 of his Travels.

to alight on the surface of the earth, and ravage it for a certain moderate extent. The storm then leaves untouched a space, appearing to have jumped or bounded over it, and alights on and ravages another part, and in that way proceeds forward. Now is it not reasonable to presume that some such force as that which is exerted by the gravity of descending rain, must have been instrumental in producing the peculiar effects described? These effects may be considered local results of condensation, and a fall of rain; and when the results are of a more extensive character, they operate over a wider area—when still more extensive they, in time, blend with and modify each other: and instead of storms bounding along as in the United States of America, or producing such incidents as are to be seen near Cape Horn, the upper current, or that which otherwise would be the upper current, is extensively brought down to the surface of the globe, and caused to force its way against and displace a part of the lower stratum of the atmosphere. In this way the atmospheric spaces near the surface of the globe, between tropical parts and such localities as the Himalaya Mountains, Norway, Tierra del Fuego, and California or New Albion, become occupied by a moist, warm and disturbed aerial current, flowing from parts where evaporation has furnished steam in abundance to other parts where that steam is freely condensed. But a sudden descent of air in a particular locality, resulting from great condensation in that locality, may display so much energy, and produce so violent a rush of the descended air, as to make it a storm; and the force of the storm will be determined by the quantity of rain formed in the higher regions, or the velocity of the upper atmospheric current brought down by the rain, or by both causes acting together.

ON

THE IRREGULAR FLUCTUATIONS OF THE MERCURY IN THE BAROMETER.

As the column of mercury in the barometer balances the weight of the atmosphere which rests upon it, the height of the mercury must exhibit the amount of that weight. But the height of the column alters so much, from time to time, as to make the extreme range of the alterations at the level of the sea about three inches; and, of course, the weight of the aerial column must vary to the same extent. Now, what is the immediate operating cause of this variation in the weight of the atmosphere? This is a question which has been often asked without any satisfactory reply having been given, though many attempts have been made to answer it.

It is, however, generally admitted that the fluctuations of the barometer are, in some way, consequent on variations in the temperature of the atmosphere: many other influences have been pointed at, but change of temperature is generally presumed to be the cause, although the way in which it acts is not seen. Supposing this presumption to be correct, it removes the difficulty only a single step, as we have still to ascertain what can produce such a variation of temperature as shall alter the weight of the aerial column to the extent that is often experienced. The general average height of the mercury at the level of the sea being 30 inches, the weight of the atmosphere is, of course, equal to that height of mercury, and as the fluctuation is, in some parts, about three inches of mercury, the alteration in the temperature of the atmosphere must be great to produce such an effect.

Within and near to the tropics the sun heats the atmospheric mass and causes it to expand, rise, and occupy additional space above the surface of the globe, but that does not materially reduce the pressure of the aerial column against the mercury in the barometer within the tropical regions, because the heating by the sun operates so slowly as to allow such a moveable body as the atmosphere to supply the place of the expansion above by an influx of air below, and this prevents any great disturbance of the pressure. But much of the heat of the sun that impinges on the surface of the globe is not accumulated there, but unites with water, and converts that water into aqueous vapour or steam, which flies from the part, taking the heat with it in a latent form. Let us then endeavour to follow this steam, and try to ascertain whether it is the heat that it contains which, by disturbing the temperature, alters the pressure of the atmosphere in certain localities, and causes the fluctuations of the column of mercury in the barometer.

There are many localities on the surface of the globe where the heat which has been taken up by evaporation is freely given out by condensation when much rain falls, but none where the effects are of a more striking character than in the neighbourhood of Cape Horn. The solar heat taken up by the water of the Southern Pacific Ocean is, in the form of steam, conveyed to the mountains of Tierra del Fuego, and is there, by the condensation of the steam, when copious rains fall, liberated, and left to attach itself to that portion of the atmosphere with which it is in contact, to raise its temperature and cause it to expand. The way in which this liberated heat expands the atmospherical gases has been explained in a paper on the formation of the cumulous cloud, published in the *Philosophical Magazine* for August, 1841. It was there shewn that the liberated heat increased the elasticity of the gases, caused them to expand into a wider space, pushed the adjoining mass of air away, raised that which was above, and caused it to flow over to adjoining parts, and thus removed a portion of the weight of the atmospheric column in the locality.* This is what apparently takes

* See also page 9.

place in the part of which we are speaking, the southern extremity of America, when rain falls freely. Captain FOSTER, who erected an observatory in 55° of south latitude, says—"The height of the mercury is perpetually fluctuating, shewing a constant change in the aerial column." And the mercurial column is generally low, as he states that "the barometer at Cape Horn, Staten Island, and New South Shetland, scarcely ever reaches 30 inches, and the mean of the year is 29.3 or 29.4." Captain FITZROY also speaks of this locality in a similar way, as being furiously windy, and drenched with rain, but as being warm in the winter for the latitude. He has given an account of the state of the barometer in various places in the neighbourhood, and among them are observations off

Diego Ramirez, from January 1 to January 14—44 times, average 29.19
Goree Road.... from January 15 to January 23—46 times, average 29.57
Berkley Sound, from March 1 to April 6—44 times, average 29.47

shewing an uncommonly low average state of the mercurial column, and consequently of atmospheric pressure.

Although it was during the summer of this part of the world when most of these observations were made, yet the sun was so obscured by clouds that it was not often seen, and its rays had such slight effect on the ground as to leave the summer very cold, having more the appearance of a wet and mild winter than a summer of the latitude.

On examining the meteorological facts that have been furnished respecting this remarkable region of condensation, it will appear that we are justified in concluding that the condensation of steam, and consequent liberation of heat, which evidently take place, in the part, cause a boiling up and overflowing of the atmosphere, and that that boiling up and overflowing not only produce variations of atmospheric pressure, but prevent the atmosphere from there settling down in its full quantity and weight, and hence the low average state of the column of mercury in the barometer. Now if such causes can so affect the barometer in this part of the world, may we not infer that wherever that instrument is similarly affected, causes similar in their nature may possibly have produced the results?

In the British Islands there are extensive fluctuations of the barometer, and to those islands steam is taken in great abundance from the West Indies and the Atlantic, and a considerable portion of it is there condensed into rain. There is, indeed, occasionally the same kind of boiling up and overflowing of the atmosphere from the condensation of steam over the British Islands, as that which takes place at the southern extremity of America, and with the same kind, though not amount, of effect on the barometer.

But there are also localities of condensation where that condensation is great, and yet where equally great alterations of the barometer are not produced, and how is this to be accounted for? The western coast of Hindoostan, and South America, near the source of the Amazon, have, no doubt, greater amounts of condensation than either Cape Horn or the British Islands, yet they do not ordinarily

experience as great fluctuations of the barometer! For this difference of results in different places, where similar causes seem to be in operation, the following reasons may be suggested. Within the tropics ordinary condensation of steam is generally considerable in its aggregate amount though proceeding slowly, and a consequence of this must be, that the whole of the atmosphere will be there heated *by condensation*, up to a considerable height and over a large area. It will, however, not only be heated, but raised to a greater height than in other parts, and by its superior height make up for its inferior density. And in any particular locality of condensation in such an atmosphere, an ascending current of warmed air may not rise as suddenly, nor as readily flow over at the top, or in a high part, as it would in a colder latitude, seeing that the whole atmosphere is there warmed, and raised to a greater height. If this view is correct even local condensation within the tropics will result in contributing, in a greater degree, to the general overflow of the tropical air, than in any particular overflow in the locality which shall affect the atmospheric column at the surface of the earth.

When condensation takes place near the surface of the globe the whole effect of the removal of a part of the incumbent air is experienced near the surface within a small area, and each and every part of that area is materially affected; but when the condensation occurs at a greater elevation the effect of the removal of the same quantity of air is spread over a larger area, and the surface, in every part of that area, is less affected. The alteration in the pressure of air on the mercury in the barometer will, therefore, be proportioned, not to the amount of condensation alone, but also to the extent of area over which the lightening effect of that condensation is spread.

Again, when condensation takes place contiguous to the surface nearly the whole atmospheric column is affected by the heating, and the lower and denser part is raised, but when that condensation occurs at a considerable height the denser part of the atmosphere is not expanded by the heat, but that expansion is confined to the rarer part above. Say that the density of the atmosphere at the surface of the earth shall be expressed by 1.00000

then at the height of 5,000 feet it will be as... .82656
at „ 10,000 feet „ as... .68321
at „ 15,000 feet „ as... .56472

so that at the last named height the density is not much more than one half of that of the surface. Condensation at the height of 5,000 feet would expand air of more than three-fourths of the density of that at the surface, whilst the same amount of condensation at the height of 15,000 feet would have air of little more than half the surface density to act upon. It will follow from this statement that, with an equal amount of condensation, the barometer will be less affected in the tropical regions than in the colder latitudes, *from two causes*—first, from the superior height at which that condensation takes place, spreading the reduction of atmospheric pressure over a larger area, and, secondly, through the condensation taking place in more attenuated air.

Supppose condensation to some given extent to take place over London at a height of say 3,000 feet, and that the consequent increased elasticity of the air at that height should throw off a part of the column of air that rested on London. As the comparative vacuum was formed at a height of only 3,000 feet, it is evident that the reduction of atmospheric pressure on London would be more than it would be if the same amount of condensation took place at a height of say 6,000 feet. In the former case the whole effect might be confined to London, and a barometer placed in any part of it would fall considerably, whilst, in the latter case, the same amount of reduction of pressure would be extended over a wide area, and each part of the surface within that area would be but slightly affected by it. Now we have only to conceive that at Bombay, or at any other part within the tropics, condensation generally takes place at the height of 6,000 or 9,000 feet, whilst at London it occurs at a height of 3,000 feet, to account for the different effects on the barometer of the same amount of condensation in various latitudes. Were it not for the larger amount of condensation that takes place within the tropics, and parts under tropical influences, the effects on the barometer would probably be scarcely traceable in those parts.

An increase in the temperature of a limited portion of the atmosphere of one degree causes it to occupy, under ordinary circumstances, a four hundred and eightieth part more space, the remaining weight in the original space will consequently be less by a four hundred and eightieth part. A sudden increase of temperature of one degree, in any particular locality, in the atmosphere, would, therefore, reduce the weight of the air in the part to the extent named: and the mercury of a barometer placed in the part would exhibit a fall to a corresponding extent. A greater increase of temperature would of course have a proportionally greater effect. The following table shews what would be the reduction in the weight of the atmosphere, and the consequent fall of the barometer, if a limited extent of that atmosphere had its whole column suddenly heated to the degrees named.

Increase of Temperature.	Proportional reduction of weight of the Atmosphere.	Fall of the Barometer.
1°	a 480th part	$\frac{1}{16}$ of an inch.
2°	a 240th „	$\frac{1}{8}$ of an inch.
4°	a 120th „	$\frac{1}{4}$ of an inch.
8°	a 60th „	$\frac{1}{2}$ of an inch.
16°	a 30th „	1 inch.
32°	a 15th „	2 inches.
48°	a 10th „	3 inches.

From this table we see that an increase in the temperature of the whole column of the atmosphere, within a particular locality, of only 4°, would be sufficient to lower the barometer to the full extent that it ordinarily ranges within the tropics. But if only a part of the

atmospheric column has its temperature increased, then a greater increase, in that part, would be necessary to cause such a reduction in weight as is pointed out in the table. To produce a fall of three inches of mercury the temperature of the whole column must be raised 48°. There are places in the world, as in Yakutz, in Siberia, where the temperature is sometimes as low as 90° below freezing, and should condensation of steam take place where the temperature is so low, the local temperature might be raised to, and for some time be kept at, the freezing point, and of course be raised 90° ! For conversion of steam into water might raise the temperature to or even above the freezing point, and if the extreme cold of the part should soon cool down some of the particles of water, and convert them into snow, the congelation would give out fresh heat, which might, for some time, keep the temperature up to 32°. Here then would be a local difference of temperature, not of 48°, as is shewn by the table to be required to lower the barometer three inches, but of 90°. We are not, however, to suppose that the whole column would ever be thus warmed, but the part where condensation forms a cloud might exhibit a rise of full 90° of temperature above that of the air in the neighbouring parts at the same altitude.

It has been shewn that the upper parts of the atmosphere in the temperate regions are not as regularly and abundantly supplied with heat, by the condensation of steam, as those of the tropical regions, and, therefore, the upper parts of the temperate regions will more nearly take the temperature due to the latitude and elevation alone : condensation will, consequently, there take place at a lower elevation, and the reduction of atmospheric pressure, which follows condensation, will be experienced in the locality at the surface of the earth, in any particular part of it, in a stronger degree, which will be shewn by the alterations of the barometer. Mr. DANIELL says—"Between the tropics the fluctuations of the barometer do not much exceed a quarter of an inch, while beyond this space they reach to three inches."—*Page* 108. And Dr. DALTON says that "at Kendal the mean range, for five years, was 2.13 inches—the greatest range was 2.65 inches." But all parts of the temperate regions will not be affected alike in this respect. The currents flowing from the tropics, which are found in those temperate regions, carry with them tropical influences, and the barometrical movements within them, will, according to their distances from the tropics, be affected by those tropical influences. Thus the higher regions of the atmosphere in the south-west current of the Atlantic, and of Western Europe, will, be warmed by the influence of ascending steam, to a greater extent than will be found over the northern parts of the continents of Asia and America: and with *equal amounts* of condensation, at any one time, the fluctuations of the barometer will be greater in the latter than in the former parts. The same reasoning will equally apply to all the other return tropical currents. This tropical influence will also be the greatest at that period of the year, when the most abundant supply of steam is obtained from the tropics. It will thus be found that, should condensation at some particular period take

place over the northern part of the continent of Asia, or of America, to an extent equal to that which is going on in the same latitude in the return tropical current, it will produce a greater effect in the former than in the latter part, on a barometer placed on the surface of the earth, because in the former case the condensation will be effected at a lower level! Accounts given by Dr. DALTON are in accordance with these views. The Doctor says—"In the temperate zones the range and fluctuations of the barometer is always greater in winter than in summer;" and that "the barometrical range is greater in North America than in Europe, in the same latitude." The height at which condensation takes place in different seasons and latitudes may be conjectured from the heights at which clouds form. Dr. DALTON represents their under sides as being below 1,300 yards in winter and 2,000 yards in summer. Clouds are represented by HUMBOLDT to be much higher in tropical America than in Europe, and they probably are generally so in all parts of the tropics.

The mean height of the barometer, in a cool latitude, is lower in a region of great condensation than in a dry region, other circumstances being alike, because in the former the whole atmosphere is, to some extent, heated, expanded, and a portion made to flow over to adjoining regions, thus making the whole remaining portion of less weight than before; in the dry region, no such general heating takes place; and the air, being thus left cool, settles at its full density and weight. And the barometer falls and rises over extensive areas at the same time, in so similar a manner, as to indicate that some common cause affects the weight of the atmosphere throughout the whole of the area; because whenever a broad current of air, highly charged with steam, flows to a considerable distance, condensation may take place, and the pressure of the atmosphere be reduced, at the same time, over the whole area of the current. The atmospheric current that flows over the west coast of Europe is broad, and it extends from America to beyond Switzerland, and in that range we may have such an overflow of the warmed air as shall reduce the weight of the aerial mass throughout the whole of its extent at or about the same time. It is not necessary that this should be the effect of a single swelling produced by condensation as large as the area, but it may be any number of smaller ones, and they may run into each other, and the whole may have a joint effect on the barometer, though the influence of any particular local ebullition may be traceable. The upper part of the atmosphere in this locality, in the autumn or the beginning of winter, may be conceived to rise and overflow to the westward on North America, and to the eastward on Northern Asia. In the summer the overflow may be more to the north, as it is presumed that the descent of the warmed air will always be in that direction in which the coldest and, consequently, the shallowest atmosphere exists. Cape Horn is a locality of great condensation, surrounded, at some certain distance, by air of a temperature and density due to the latitude alone; now, on heat being liberated by condensation about Cape Horn, the air

will boil up and overflow, and less than the average weight will be left to press on the surface of that part of the globe. And the supply of steam being sufficiently constant to cause the boiling up and overflowing to continue, this inferiority in quantity and weight of air in the part may continue, and the barometer may, through all its fluctuations, mark a low average degree of atmospheric pressure. It is possible that the barometer shall be occasionally low when the weather is fine, if it be placed in the centre of a large area of condensation, where the rain produced is poured outward, on all sides, from the centre! It is indeed evident that there may be neither clouds nor rain in the centre of such an area as that described, when condensation has continued for some time, as no supply of steam may reach that part, all having been intercepted in the outer portions of the area.

In other localities we find a current of air cool and dry for the latitude, and consequently almost without condensation. In these we may expect to have the full weight and pressure of the air, and the barometer to range accordingly. Such localities appear to exist about the Cape of Good Hope and Valparaiso. These places may even have the barometer standing above the general mean height, as they are so situated as to be likely to receive an overflow of air from neighbouring regions of condensation which has been cooled in its descent. The Cape of Good Hope is placed in the great south-east current which is passing towards the tropical regions, and may possibly receive an overflow from the return current, which, proceeding from the southern tropic, blows from the north-west and passes south of the Cape, and is, as Captain Hall says, "generally tempestuous." Valparaiso experiences but little rain, and has, therefore, we presume, its full quantity of air, and may also receive an overflow from the region of condensation south of it, and may, consequently, have a high barometer. It is very likely that in all regions of copious and continued condensation, particularly in high latitudes, the mean of the barometer will be found low; and that where the air is generally both cool and dry, that it will be comparatively high, the disturbing and lightening causes being, in some places, such as Cape Horn, so constant as to produce that departure from equilibrium of atmospheric pressure to which air always tends. If this view is correct, all aerial currents, proceeding from cooler regions, towards the equator, and containing but little steam for the temperature, will have a barometer, which may be placed in them, range comparatively high, whilst all currents in which condensation is taking place freely will shew a barometer comparatively low.

The following observations, by Captain Foster, have a bearing on this subject. He says—"At the Cape of Good Hope the barometer ranges, throughout the year, from 29.7, the minimum, to 30.6, the maximum, the mean state being 30.22. The barometer has a higher range in winter than in summer. The average difference between the atmospheric pressure of Cape Horn and the Cape of Good Hope is nearly one inch of the barometer! At Valparaiso, on the coast of Chili, the barometer stands equally high as at the

Cape of Good Hope. Are there not (says Captain FOSTER) zones of atmospheric pressure as well as of temperature? The mean pressure within the tropics is 30 inches with a small fluctuation, a range of not more than 0.5 inches during the year, while that of the extra tropical, to the latitude of 40°, perhaps have the highest mean barometer 30.2 or 30.3 inches, and a greater range of fluctuation amounting to an inch or an inch and a half. Again, in the cooler latitudes, from 40° to 60° and upwards, there is an unequal and fluctuating range, the mean pressure being below 30° and about 29.8, with a wide range from 28.1 to 30.8, being 2¾ inches." "In the Island of Ascension the barometer never rises above 30.1 nor falls below 29.8—the mean for the whole year is 29.95."

Mr. DANIELL says—"As we advance towards the polar regions we find the irregularities of the wind increased, and storms and calms alternate without warning or progression;" and he goes on to say of these regions, quoting from SCORESBY, that "the extremes of heat and cold will sometimes prevail within a very limited compass, and forcible winds will blow in one place, when at a distance of a few leagues gentle breezes prevail. Ships, within the circle of the horizon, may be seen enduring every variety of wind and weather at the same moment; some under close-reefed topsails labouring under the force of a storm, some becalmed and tossing about by the violence of the waves, and others plying under gentle breezes, as diverse as the cardinal points. The fluctuations of the barometer are also great and sudden!" The causes which produce ascending aerial currents must, in the regions here described, act in an isolated manner on small extents of surface, as they produce such different results within so small an area; but the fluctuations of the barometer shew that those causes greatly altered the weight of the atmosphere within small distances.

In the very cold polar regions but little steam exists in the atmosphere. The water, too, is generally covered with ice, which obstructs evaporation. But there are occasionally holes and openings in the ice, and in these situations evaporation takes place freely. The temperature of the air being say 70° below freezing, not very uncommon in these parts in the middle of winter, the probability is that the dew-point would be still lower. Now on water of 32°, in the openings of the ice, being exposed to air, with a dew-point of say 70° below freezing, evaporation would take place about equal to that which would arise from water of 110° in air with a dew-point of 40°, which is often the state of our atmosphere in this part of the world in cool weather. And we know that much steam rises from water of 110° in such weather. Steam would, therefore, spring freely from the water, taking with it a part of the heat which the water contained. But in such a cold atmosphere as that under consideration this steam would be almost immediately condensed, and made to give out its heat to the air; and the air, thus heated, would rise; and this process of evaporation and condensation being continued an ascending current of comparatively warm air must be formed, commencing from a level near the surface.

With a temperature of 70° below freezing, when evaporation takes place from the surface of water, and steam passes into the air, not only does condensation of the steam soon follow, but congelation also of the particles of water produced by the condensation. There is, therefore, a double liberation of heat—first that which was latent in the steam, and next that which was latent in the water; and both these quantities of heat are given out to the air and warm it: and this double process takes place wherever cloud, and snow or hail are both formed in the air. Now in such an atmosphere, suppose a considerable area of water of 32° to be suddenly exposed by the removal of ice, and the following phenomena, it would appear, must occur. First, steam would spring freely from the surface of the water into the air, where a part of it would be almost immediately condensed and its heat liberated, producing the commencement of an ascending aerial current. This current would take the remainder of the steam, together with the particles of water, to a higher level, where fresh condensation would take place, and thus the process would be repeated, and any little steam that was previously in the atmosphere would be carried up with the current, and, at a proper height, be condensed and form a cloud. At a certain stage in the process the great cold of the part would freeze the small particles of water which constituted the cloud and convert them into snow, thus furnishing more heat to feed the ascending current, which would, consequently, rise rapidly, and expand over the neighbouring regions of the cold and dense, and therefore low, atmosphere, leaving a smaller weight of air to press on the surface of the earth, in the particular part where the condensation and congelation had taken place. A barometer placed in this particular part would shew evidence of greatly diminished pressure, because the base of the heated air, which produced the ascending current, was near the surface of the earth where the barometer was placed.

In parts of the polar regions where the temperature is much below freezing, at the surface of the earth, clouds are occasionally seen. These clouds may be formed from steam brought from warmer regions by an upper current, or from other steam, the product of recent evaporation in the part. But from whatever quarter the steam may come the liberation of its heat, by condensation, will tend to raise the temperature of the part of the atmosphere where the condensation takes place as high as, or even higher than, 32°, and the buoyancy of the part, and the rapidity of the ascending current, will be proportioned to the difference of temperature between the cloud and the cold air adjoining of the same altitude. Now, on some particles of water in a cloud being converted into snow the latent heat would become sensible, and the intermixture of the snow and the remaining particles of water would be disposed to take the temperature of 32° for the same reason that snow or ice put into water would cause the mixture to take that temperature. Consequently, when snow of a lower temperature than 32° falls to the earth, that lower temperature may have been acquired, not in the part where the freezing took place, but in some other part through which the snow subsequently

passed. However cold, therefore, it may be at the surface of the earth where snow is falling, we may conclude that, in the part of the atmosphere where it was formed, the temperature at the time of its formation was not lower than 32°. It follows from this that a great formation of snow, in a very cold part, must give considerable buoyancy to the atmosphere in the part where it is formed, and must cause a local rise and overflow; and, the buoyancy commencing near the surface of the globe, would be attended by a considerable fall of the barometer in the locality.

Captain PARRY has various passages descriptive of what takes place in the polar regions. He says—"while the atmosphere near the ships was so serene and undisturbed, that the smoke rose quite perpendicularly, we saw the snow-drift on the hills, at one or two miles distant, whirled up into the air in columns several hundred feet high, and carried along by the wind sometimes to the north, and at other times in the opposite direction."—*Page* 252. The Captain does not say what produced this ascending current; but if a barometer had been placed under it, it is probable that the mercury of that barometer would have suddenly fallen, while another near the ships might not have been affected. In another part he says—"When any great extent of water is seen, the frost smoke, of course, is very much increased, and entirely hides the horizon from the view, seldom, however, rising above 2° in altitude, and presenting, by its dusky grey clouds, a fine foil to the matchless blue of the sky in frosty weather."—*Page* 94. Here the intense cold in the part soon converted the steam which arose into minute particles of water and formed cloud, but the cloud itself was, by the same cold, frozen before it could reach any considerable height. The following passage will shew the result of such congelations:—"The deposition of small snow, which I have observed as almost always going on in these regions in the winter, took place this evening in occasional showers, so thick as to oblige us to cover the instruments with which we were observing, though the stars were plainly visible all the time, and the night was in every other respect what would generally be called clear."—*Vol.* 3, *page* 165.

Hail cannot be formed in such a climate, because the watery particles constituting cloud cannot be carried sufficiently high to enable large drops of water to form before congelation commences. The fact of the non-formation of hail in cold climates had been noticed by DALTON, who observes that "it scarce ever hails in latitudes higher than 60°." And he says, in another part, that "in winter, during a frost, if it begins to snow, the temperature of the air generally rises to 32°, and continues there whilst the snow falls." —*Page* 183.

From other facts observed in the cold regions named it would appear that the air, warmed by the condensation of steam in the higher part of the atmosphere, frequently descends to the lower region at some distance from the place of its ascent; hence, perhaps, the thaw which often succeeds to a fall of snow in our temperate climate. In the polar regions the great change, which must be produced in

the temperature of the higher parts of the atmosphere by condensation, causes that change to be felt in the lower part in a more sensible degree than in warmer latitudes. This change is noticed by navigators when speaking of the rise of temperature which accompanies a wind. In Parry's first voyage to discover a north-west passage, in 1819, we have the following statement—" From midnight on the 29th till two o'clock on the following morning the thermometer rose from—46° to—40½°, and at half past three a gale came on from the northward, which continued to blow and the thermometer to rise till the latter had reached—21° at midnight. This was one of a great many instances which occurred during the winter of an increase of wind, from whatever quarter, being accompanied by simultaneous rise in the thermometer."—*Page* 199.

Again—" From four P. M. on the 14th (February) till half-past seven on the following morning, being an interval of 15½ hours, during which time the weather was clear and nearly calm, a thermometer, fixed on a pole between the ships and the shore, never rose above —54°, and was once during that interval, namely, at six in the morning, as low as —55°. This low temperature might perhaps have continued much longer, but for a light breeze which sprung up from the northward, immediately on which the thermometer rose to —49°, and continued still to rise during the day, till at midnight it had reached —34°."—*Page* 237.

In a region so intensely cold as this was, any considerable amount of condensation must have greatly raised the temperature in the part where it took place, and must have produced an ascending current. Yet the first effect of the ascending current on the adjoining lower air must have been to cause it to expand, and, therefore, to become somewhat colder. But as the thermometer showed that the wind became warmer, it is reasonable to infer that warmed air had in some way come down to the surface of the earth, for from what other quarter could it have come? And it is not improbable that portions of the atmosphere, under such circumstances, may take a form approximating to that of a vertical wheel, ascending in one part and descending in another, at some distance from which other part the descended warm air may flow towards the ascending vortex, and constitute a warm wind. But as the wind thus warmed would be dry, it could not continue to furnish the ascending current with steam, and, therefore, the process would soon cease.

From these facts and reasonings it appears that the greatest fluctuations of the barometer must arise from the partial heating of a portion of the atmosphere where it is cold and shallow; as then the heated air will rise rapidly, and overflow to adjoining parts, and the effect of the removal of a part of the heated column is experienced at so small a distance from the surface of the earth as to cause it to be confined to a small area, within which area the atmospheric pressure is materially diminished, and the mercurial column sinks. In the temperate regions, and more particularly in the warm and moist parts, the base of the column of heated air will be at a greater distance from the surface of the earth, and the effect of any overflow

will be extended over a wider area, whilst it will be less in each particular part. Within the tropics, and in parts with moist tropical climates, the base of the heated air will be still higher, and among more attenuated air, the range of the effect wider, and the influence will be found less on each separate part of the surface. And thus, the amount of condensation of steam being the same, the more extensive the area affected the smaller will be the reduction of atmospheric pressure within it, and the less the fall of the barometer at any one point.

ON THE SEMI-DIURNAL OSCILLATIONS OF THE BAROMETER.

We now come to consider the causes of those semi-diurnal oscillations of the barometer which have excited so much attention in many parts of the world, and which have hitherto defied all attempts to explain them. Contrary to what is experienced in the irregular fluctuations, these semi-diurnal oscillations are the greatest in tropical parts, and diminish considerably in the temperate regions; whilst they are, probably, extremely small near the poles.

In the ninth volume of the proceedings of the British Association for the Advancement of Science, is a report from Mr. W. S. Harris, on 26,280 hourly observations of the height of the mercury in the barometer, at Plymouth, in the years 1837, 1838 and 1839. From this report it appears that, during these years, the mean daily pressure of the atmosphere was equal to 29.800 inches of mercury very nearly, which is exhibited on a diagram shewing the risings and fallings during the twenty-four hours. The times of rising and falling are,

1st period, 6 hours, from 4 A. M. to 10 A. M.
2nd period, 6 hours, from 10 A. M. to 4 P. M.
3rd period, 6 hours, from 4 P. M. to 10 P. M.
4th period, 6 hours, from 10 P. M. to 4 A. M.

And the following is a table of the heights of the mercury at the four turning periods, namely, at

Hours.	4 A. M.	10 A. M.	4 P. M.	10 P. M.
Inches.	29.793	29.806	29.790	29.810

In the diagram curve, given at the end, representing the mean pressure, and the risings and fallings of the mercury, together with the table of the heights of the four periods, it will be seen that the

morning *rise*, from 4 o'clock, commences from a height of about 29.793 inches, and by 10 o'clock reaches 29.806 inches. And the evening *rise* commences at 4 o'clock, from a height of 29.790 inches, and by 10 o'clock at night reaches 29.810 inches; so that the former rises .013 and the latter .020 of an inch. The *fall* from 10 A. M. to 4 P. M. is from 29.806 inches to 29.790 inches, or .016; and that from 10 P. M. to 4 A. M. is from 29.810 to 29.793 inches, or .017. The greatest departures from mean pressure are in the fall from 10 A. M. to 4 P. M., when the mercury sank to 29.790 inches, and in the rise from 4 P. M. to 10 P. M. So that the greatest disturbances took place from 10 o'clock in the forenoon to 10 o'clock at night.

Mr. HARRIS speaks of each rise and fall of the barometer as shewing a tide in the atmosphere; but it is sufficiently evident that the atmospheric tides are not caused by the attraction of gravitation, as no influence of the moon can be traced in the times of their occurrence. That they are connected with the solar influence is indicated by the relation which they preserve to the daily apparent movement of the sun. Inequality of temperature in the atmosphere seems the most probable cause of the oscillations, yet the temperature produced by the sun on the surface of the earth, as measured by the thermometer, is increased during the former part of the day and progressively diminished during the latter part and the night, as may be seen in the thermometric curve in the diagram. This curve shews that the daily movement of temperature at the surface of the earth is as follows. It begins to rise a little before the sun, increases until about one o'clock in the day, when it turns and declines; and continues falling until about five o'clock the next morning—making but one rise of eight, and one fall of sixteen, in the twenty-four hours. From these facts it sufficiently appears that the two daily atmospheric tides or movements cannot be caused directly by the sun heating the surface of the earth.

By comparing the height of the wet bulb thermometer, the curve of which is given in the diagram, with that of the ordinary dry bulb thermometer, we trace the effect of evaporation in cooling that instrument. This evaporation also shews that steam is then in the process of being formed from wet surfaces and thrown into the atmosphere; whilst the dew-point curve, which is also given, exhibits the quantity of steam existing in the atmosphere at the time. By tracing and comparing these facts we shall be enabled to see the nature and extent of the alterations that are going on, first, from changes in the temperature, and, secondly, from alterations in the quantities of steam to be found in the atmosphere. And to do this we will divide the twenty-four hours into four periods, corresponding with the oscillations, as No. 1, 2, 3 and 4—the first and third shewing the two risings, and the second and fourth the two fallings of the barometer.

During the first period, from 4 to 10 A. M., the thermometer rises 6°, which expresses the rise of the temperature near the surface of the earth, whilst the wet bulb thermometer rises only 4°, shewing

that evaporation had become more energetic: and the result of that greater energy of evaporation is seen in the rise of the dew-point about 2°, through the additional steam thus thrown into the atmosphere. Now, the tendency of the increase in the temperature, which took place during this period, was to make the atmosphere lighter, and thus to cause the barometer to fall; but the additional steam, which had been produced by evaporation, had the opposite tendency, as the increase in the pressure of the steam against the mercury would tend to make the whole atmosphere heavier, and the barometer to rise. A local increase in the temperature of the atmospheric column of 6° would produce a fall of the mercury of say .375 or $\frac{6}{16}$ths of an inch, whilst the additional steam, furnished as marked by a rise of 2° of the dew-point, would cause a rise of the mercury of say .024, or a little less than a fortieth of an inch.* But we see that the barometer during the time rises .013, so that all the influence of the higher surface temperature is apparently expended in counteracting the rise of the barometer. 011. From these facts it becomes evident that that increase of temperature, which is marked by a thermometer placed near the surface of the earth, produces but a small effect on the pressure of the atmosphere, as was indeed shewn when treating on the influence of surface temperature in producing sea breezes.

From 10 A. M. the mercury begins to fall, and continues falling during the second period, that is, till 4 P. M.; and we have now to ascertain what are the alterations which occur in the surface temperature, and in the quantity of steam thrown into the atmosphere, by evaporation, during this period. It is, however, desirable that we should divide it into two parts—one from 10 A. M. to 1 P M., and the other from 1 to 4 P. M., in order that we may see more distinctly the alterations that take place.

From 10 to 1 the surface temperature rises nearly 2°, and the dew-point rises about 1°, which takes place from 10 to 11 o'clock; but the barometer, instead of continuing to rise, as it did from 4 to 10 A. M., when the same two causes were in operation, now falls! and during these three hours falls say .007 of an inch of mercury. Thus the direction of the influence of the two causes in operation is now reversed; for, from 4 to 10, the rise of surface temperature 6° counteracted, to a small extent, the pressure of the additional steam, but from 10 to 1, when the rise is less than 2°, it seems fully to counteract that pressure, and also to lighten the mass of the atmosphere enough to cause the mercury to fall .007!

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* The forces of steam, as given in DANIELL'S tables, at the dew-points exhibited in the curve, are as follows, viz.

at 44° —	.328	of an inch of mercury.
45° —	.340	do.
46° —	.352	do.
47° —	.364	do.

thus shewing that a rise of the dew-point 1° increases the force of atmospheric steam .012 within this range of the dew-point.

From 1 to 4 P. M. the air cools, as the surface temperature falls, and the dew-point remains unaltered; we ought, therefore, to find the cooled air produce its full natural effect on the barometer in making it rise, for now, as the dew-point remains stationary, there is no cause in operation, yet adverted to, but the cooling of the air, which ought to make the mercury rise, but, instead of rising, it falls say .009! shewing that the causes hitherto traced as being in operation are insufficient to account for the effect produced.

But let us take the whole of the second period, and trace the natural results of the alterations in the surface temperature, and the change of the dew-points, and compare those results with the actual movements of the mercury in the barometer. First, then, we observe, that the surface temperature at the end of this period was the same as at the beginning, namely, 53°, and, therefore, the influence of temperature should have left the mercury at the same level at the conclusion that it was at the beginning of the period: but we have seen, that it had fallen .016 of an inch, whilst the dew-point had risen 1°, which should have produced a small rise instead of a fall of the barometer; this fall, therefore, cannot be attributed to any alteration of either surface temperature or of the quantity of steam in the atmosphere, and we have to discover the real cause that produces the fall during this period.

The rise of the barometer during the first period, we will presume, then, is attributable to the additional steam thrown into the atmosphere by evaporation, as that is an adequate cause for the production of such a rise. But there is reason to believe that this evaporation continued during the second period, as the difference between the temperature marked by the wet bulb and that marked by the dry bulb thermometer proves that that evaporation was then going on. Indeed evaporation must evidently have been more active and energetic at this time than it was in the previous period, as it will be seen, by the diagram, that the wet bulb thermometer was cooled down by evaporation to a greater distance below the temperature marked by the dry thermometer than it had been previously, and, consequently, much additional steam must have been thrown into the atmosphere. But why, then, was the weight of the atmosphere, as measured by the barometer, not increased by this additional steam? or, rather, why did the barometer fall instead of rising? It could not be any alteration of surface temperature that caused the fall of the barometer, because we have seen that that was the same at 4 P. M. that it had been at 10 A. M.! And the necessary effect of the weight of the additional steam that had evaporated, and passed into the air, must have been to produce a rise. Thus, these two causes tended to produce the opposite effect to that which occurred, and there must, consequently, be some other cause sought to account for the effect produced on the barometer during the second period.

Say, then, that the additional steam thrown into the atmosphere by evaporation, in the first period, causes a rise in the barometer, which rise was checked to some extent, by the increase of surface

temperature; and the general result, by 10 A. M., was such a rise as has been shewn. But at 10 A. M. steam continued to rise through the increase of temperature, although it disappeared, as we do not trace its existence in a further rise of the dew-point; but what became of it? It, no doubt, became condensed into small particles of water, and formed a floating or ascending cloud: and from 10 A. M. to 4 P. M., that is, during the whole of the second period, the steam produced by evaporation was condensed into cloud, and thus was prevented from appearing in a higher dew-point. By carefully observing all the facts presented to us, first, in the temperature of the ordinary thermometer—secondly, in the state of the wet bulb thermometer—and, thirdly, in the stationary condition of the dew-point, it becomes sufficiently evident that steam must have been freely produced during this period, and also that it must have been condensed and formed into cloud. The process here described may be seen in many parts, taking place with considerable regularity, cumulous clouds beginning to form about 10 A. M. and increasing till about 4 P. M., when the process generally ceases. Now the effect on the barometer of this additional portion of steam thus thrown into the atmosphere, and remaining there, whether as an invisible fluid, the existence and amount of which was indicated by a higher dew-point, or as a cloud which remained suspended in the atmosphere, and added to its weight, must have been to increase the aggregate weight of the whole atmosphere pressing on the mercury of the barometer, and to cause it to rise. Yet we have seen that, during this same time, the mercury, instead of rising, fell! and the fall was .016, or about $\frac{1}{60}$th of an inch; we have, therefore, to seek for the cause of this fall of the barometer in some other operation of nature; and that other operation is, evidently, one of which much has been already said in these pages, the heating of the mass of the atmosphere in the locality by the condensation of the steam which had become cloud.

By referring to pages 9 and 10 it will be seen that the atmosphere may be heated, by the condensation of steam, sufficiently to cause a material alteration in its weight and pressure. If the condensation should be great enough to produce rain it may cause the barometer to fall to a considerable extent, and that fall may continue beyond the regular daily period, as has been shewn when treating of the irregular movements of the barometer. But if the condensation be only the ordinary daily result of the sun heating the surface, and causing the lower part of the atmosphere to rise, until the greater cold of the higher portion condenses some of the steam that it contains, and forms cloud, then the fall of the barometer will measure the effect of that formation of cloud, which is consequent on surface heating by the sun. If this view is correct, the surface heating, as shewn by the thermometer, acts only as an agent to raise steam to a sufficient height to produce condensation, and the heat liberated by the condensation of the steam is that which really makes the atmosphere light, and causes the barometer to fall. This view exhibits to us the causes of the semi-diurnal

oscillations of the barometer, as not only in accordance with its alterations, as far as we have traced them, namely, from 4 A. M. to 4 P. M., but also as in harmony with the more extensive irregular fluctuations of that instrument as already explained; whereas, by supposing the semi-diurnal effects to arise from alterations of surface temperature, and of the quantities of steam in the atmosphere, we suppose causes to determine them which are quite insufficient, and which are most palpably inadequate to account for the greater and more irregular fluctuations of the barometer.

We now reach the third period, from 4 to 10 P. M., when the mercury rises. And, by comparing the curve of the dry with that of the wet bulb thermometer, it will be seen that, during the same time, evaporation was less active; and the fall of the dew-point shews that the quantity of steam left in the atmosphere, at the surface, was reduced. With reference, therefore, to the steam pressing on the mercury we ought now to have a fall of the barometer. But the barometer does not fall—on the contrary, it rises .020, being considerably more than equal to its fall during the previous period of six hours! It is true the thermometer shews that the surface temperature fell at the same time from 54° to 48° 5′, but if alteration of surface temperature influenced the previous movements so little, as it has been shewn it did, we cannot suppose that it would produce so great an effect as a rise of the barometer of .020 during these six hours. But then what can be the cause which thus counteracts the natural result of a reduction of the pressure of steam on the barometer? Why, it may be presumed to be—evaporation of the cloud that had been previously formed; as that is not only adequate to produce all the effects, but it is a cause which, it may be shewn, must have been in operation at the time, and which, from the known laws of nature, must have produced an effect of the kind that was experienced.

When condensation in the higher regions of the atmosphere ceased at 4 P. M. a large mass of cloud was left floating there. And, from the known laws of evaporation, this mass would then begin to dissolve, and cool the air in the part; for as condensation had previously heated, expanded and pressed away a part of the atmosphere, and reduced its weight, so evaporation would now cool and contract it, and additional air would flow from adjoining parts and make the whole mass in the locality heavier, and cause the barometer to rise. The cold resulting from evaporation of cloud would now increase the pressure of the atmosphere sufficiently, not only to overcome the the effect of the reduction of steam pressure, as indicated by the fall of the dew-point, but also to cause the barometer to rise .020 of an inch. And thus, it is conceived, that the movement of the barometer during the the third period is accounted for, the cold resulting from cloud evaporation being the operating cause. It should, however, be remembered that as the cloud cooled by evaporation, it, or the air cooled by it, would descend and occupy a lower level, and either the cloud itself, or the mass of air with which it was intermingled, would reach the surface of the earth, and there spread itself into a

thin stratum; as it is known the heaviest air in the part always becomes the lowest. This process causes the land breeze that is experienced in so many parts of the world, where the atmosphere is sufficiently moist to produce the daily condensation and evaporation of steam which create fluctuations of temperature and sea and land breezes.

By 10 P. M. the effects of cloud evaporation have been experienced, and then we have the second diurnal fall, which amounts to about .017. To account for this fall we have only to look at the reduction in the quantity of steam in the atmosphere by the formation of dew at the surface. The thermometer shews that the surface temperature was sinking at this time, which, if it produced any effect, would have caused a rise of the barometer—we see, however, that it falls. But the dew-point sinks from 45° 7′ to 44° 2′, which, by reducing the steam pressure .018, produces the fall of the barometer, and this fall continues until the approaching sun, by raising the surface temperature, causes fresh evaporation, and, from 4 to 10 A.M., by producing additional steam pressure on the barometer, causes it again to rise and commence its daily oscillations.

The accounts of the Plymouth observations have alone been brought forward, because they are the most full that have been published. In addition to the heights of the barometer and thermometer they give the registration of the wet bulb thermometer, and of the dew-point; and this fulness enables us to trace the production of steam by evaporation in the first morning period, its condensation to form cloud during the second period, its subsequent evaporation in the afternoon, the reduction in the steam pressure during the night, and the effects of all these changes on the general atmospheric pressure. But there are accounts from other places which, although less full, may be adverted to, in order to shew that the same causes produce similar effects in other parts, though those effects differ in degree from the changes at Plymouth. Mr. HARRIS gives tables of the semi-diurnal oscillations of the barometer at Madras and Poona, taken from accounts furnished by Col. SYKES. The following are these accounts tabulated with the Plymouth observations.

At	Rise from 4 to 10 A. M.	Fall from 10 A. M. to 4 P. M.	Rise from 4 to 10 P. M.	Fall from 10 P. M. to 4 A. M.
Plymouth	.0133	.0166	.0204	.0171
Madras	.0470	.0790	.0630	.0350
Poona	.0445	.1116	.0884	.0181

From this table it will be seen that at Madras the steam which, from the increase of temperature, it is presumed, rose in the morning period from 4 to 10, was sufficient to cause the barometer to rise .0470 of an inch of mercury, and as there is no doubt that steam

continued to rise with the rising temperature, and passed into the atmosphere at that place, such steam would have caused a further rise of the barometer during the second period, namely, from 10 to 4, had there been no cause in operation to prevent it. But at Madras, as at Plymouth, about 10 o'clock, a part of the steam, doubtless, was raised sufficiently to commence the process of condensation and to form cloud; and the formation of that cloud heated the air in the locality so much as, by 4 o'clock, to cause the barometer to sink .0790 of an inch, or nearly eight hundredths of an inch! And be it observed, too, that, at the end of this second period, it is apparent that at Madras, as at Plymouth, the surface temperature would be about the same as at the beginning of it, and, therefore, the fall of the barometer could not be caused by an alteration of surface temperature. In like manner we may say that the dew-point would be stationary, as it was at Plymouth, whilst the additional steam or cloud would tend to increase the weight of the whole atmosphere; but the heat liberated by condensation must have been sufficient to counteract the influence of this additional quantity of steam, and to reduce the pressure of the atmosphere equal to nearly nine hundredths of an inch of mercury!

The rise during the third period at Madras, produced by the cold of cloud evaporation, was .0630, being less than the previous fall from condensation, in that respect differing somewhat from the Plymouth oscillations. In the fourth period the fall of the mercury, from the presumed disappearance of a part of the atmospheric steam in the formation of dew on the surface of the earth, was .0350.

From an examination of that part of the table which relates to Poona, it will be seen that the great fall which occurred there, in the second period, and the rise in the third, indicate the condensation of a very large amount of steam into cloud, and the subsequent evaporation of that cloud. Had we the wet and dry bulb thermometers, and the dew-point registered for this part, as they have been at Plymouth, we might trace their separate effects, as has been done for that place, and thus prove, more conclusively, that the alterations during the day, that is in the second and third periods, are attributable to condensation and evaporation, and not to surface temperature and alterations in steam pressure. The analogy in the three cases is, however, sufficiently close, and there seems no reason to doubt that the same causes which produced the effects in one case produced them in the others.

Sir J. Herschel has furnished, in vol. 13 of the Transactions of the British Association, an account of the barometric altitudes observed at Mauritius during the twenty-four hours, containing the mean of fourteen months. In this account the heights at the turning points are—

At	4 A.M.	10 A.M.	4 P.M.	10 P.M.
INCHES. 30	.0343	.0794	.0199	.0841

And the observations, when dotted down, and the dots connected by lines, exhibit curves so similar in character to those already given, or treated of, as to indicate that similar causes were in operation in all the cases. The fall, from cloud formation, during the second period, from 10 A.M. to 4 P.M., was .0595, and the rise, from cloud evaporation, was .0642, and these constitute the departures from the line or curve, of one rise and one fall, which it is probable would be found if the causes in operation were only one rise of temperature, and one augmentation of steam pressure in the beginning of the day, and one decline of each in the latter part of the day and the night.

In a paper presented, in 1844, to the British Association, at York, by Colonel SABINE, containing meteorological observations at Toronto and Prague, the Colonel intimated that the variations of temperature, as indicated by the thermometer near the surface of the earth, and the alterations in the quantities of aqueous vapour (steam) existing in the atmosphere, during the twenty-four hours, sufficiently accounted for the semi-diurnal oscillations of the barometer in those places. In the tables exhibited by him, the heights of the mercury measuring atmospheric pressure, and the separate pressure of the steam atmosphere, were given, and were as follows:—

At	4 A.M.	10 A.M.	4 P.M.	10 P.M.
Atmospheric pressure.	29.602	29.634	29.590	29.608
Steam pressure.........	.234	.270	.279	.249

But it has been shewn that, at Plymouth, during the second period, in the hottest part of the day, the dew-point did not determine the quantity of steam that had passed into and remained in the atmosphere, in some form adding to its weight, as that dew-point was stationary, though the wet bulb thermometer shewed that evaporation had been very active. We must, therefore, presume that the pressure of steam, or of its product cloud, in Toronto and Prague, during this period, was greater than is shewn in this table. And after one o'clock, P.M., when the quantity of steam in the atmosphere must have been increasing, and the temperature, as at Plymouth, must have been declining, and when, therefore, from the influence of both these causes, the barometer ought to rise, we find, from the tables, that it fell! as it ought to do if cloud formation was the cause that produced the result. It should be borne in mind also that Toronto and Prague have each a low mean temperature and dew-point, and the daily formation of cloud may not take place as regularly in those parts as it does in others having higher temperatures and dew-points. The semi-diurnal oscillations in these comparatively dry parts will approximate to the state of those localities where no daily cloud is formed, such as the North African desert or the plains of Eastern Patagonia. But this difference between the movements of the barometer at Toronto and say

Madras and Poona furnishes additional evidence of the truth of the theory here advanced. The *semi*-diurnal oscillations are, it is contended, results of daily cloud formation and evaporation, and where very little or no such formation occurs the double oscillation will be but little, or not in any degree, traceable.

In some regions clouds frequently cover the earth day and night, when the morning sun cannot warm the surface sufficiently to raise the lower air, consequently a daily new cloud cannot be formed. And as the great condensation which often takes place in those regions produces a proportionately great ascent of air and steam, and causes the minute particles of water which constitute cloud to form into drops, and fall to the earth as rain, instead of being suspended in the air as cloud to evaporate, much cold air, produced by cloud evaporation, cannot descend, and considerable regular daily variations of the barometer cannot then occur in the part. Mr. Birt, in his letter to Sir J. Herschel, in the volume of the British Association for 1841, says—"One point which I have glanced at in the notes appears to me interesting and worthy of attention in future observations and discussions of this kind, namely, the appearance of the diurnal oscillations, when the extent of oscillation at the station is small, for instance, under 0.1 inches. Generally, as the oscillation increases, the diurnal oscillations become obscured." This fact, not reconcilable with any other theory yet advanced, is in accordance with that now advocated.

CONCLUSION.

In the preceding investigations, in order to avoid presenting too many claims on the attention of the reader at the same time, general laws and principal facts have alone been brought forward. The laws are admitted to exist, and the facts will, it is presumed, be found substantially correct. Any minute corrections, or qualifications, which may possibly be required, when going more into detail, may be easily supplied, without affecting the general conclusions arrived at. The object has been to point out chemical and mechanical changes, hitherto almost unnoticed, which take place in the atmosphere, and which lead to results affecting, in a most material degree, the condition of man; and, in doing this, simple statements of broad facts have always been preferred to minute fractional accuracy, excepting when the elucidation of the subject required such accuracy. But, making due allowance for trifling exceptions and fractional corrections, it is conceived that the following propositions have been established, viz.:—

That the non-condensable gases and steam, which constitute our atmosphere, cool by expansion, and by different laws;

That a result of their mixture and diffusion is the condensation of steam at an elevation due to the temperature of the gases, and not to that of the steam;

That this condensation heats the gases in the locality, and, when it is considerable, creates an ascending aerial current, which produces rain;

That the ascending current thus created leaves a comparative vacuum, into which adjoining air flows, producing a horizontal wind;

That these phenomena are sufficiently extensive and constant, in some parts of the world, to create long-continued ascending currents, and winds which blow from great distances;

That the ascending currents also produce descending winds, which are generally dry;

That the rain produced in the higher regions of the atmosphere, in many parts, brings air and steam with it in its descent to the surface of the earth so abundantly as to make the air and steam thus brought constitute lower atmospheric currents;

That those temporary and local winds called sea and land breezes are produced by the alternate local heating and cooling of a mass of the atmosphere by the daily formation and dissipation of cloud;

That storms are produced by the same causes that produce other winds, and that the greatest storms are probably descended winds;

That the irregular and greater fluctuations of the barometer are effects of more or less copious condensation of atmospheric steam, and the production of rain or snow, in different latitudes and at various elevations, and the semi-diurnal oscillations of the barometer are results of varying quantities of steam existing in the atmosphere, and of heat and cold produced by cloud formation and evaporation.

These alterations, producing rain, wind, storms, and the fluctuations of the barometer, are all in accordance with known natural laws, and in harmony with each other. And all are traceable to the general phenomena of evaporation of water, and condensation of steam; showing in this, as in other departments of nature, that the great Creator of the universe accomplishes the most numerous, and to man the most beneficial, ends by the most simple means.

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ERRATA.

In page 90,	line	31,	*read* less than *instead of* about.
„ 90,	lines	$\left\{\begin{matrix}34\\40\end{matrix}\right\}$	*read* .010 *instead of* .007.
„ 91,	line	7,	*read* .006 *instead of* .009.
„ 91,	line	18,	*read* less than *before* 1°.
„ 95,	line	20,	*read* eight *instead of* nine.